PB84-190974

Draft Environmental Impact Statement for Proposed Wastewater Treatment Facility Greene County, Missouri

Sverdrup and Parcel and Associates, Inc.
St. Louis, MO

Prepared for

Environmental Protection Agency, Kansas City, MO

Feb 84

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Region 7
324 East Eleventh St.
Kansas City, Mo. 64106

EPA 907/9-84-001
February, 1984

PB84-190974

Environmental Review

EPA

Draft Environmental Impact Statement

Draft

Proposed Wastewater Treatment Facility Greene County, Missouri

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 907/9-84-001	2.	3. RECIPIENT'S ACCESSION NO. PB84 190974
4. TITLE AND SUBTITLE Draft Environmental Impact Statement: Greene County Sewer District Proposed Wastewater Treatment Facilities, Greene County, Missouri		5. REPORT DATE February, 1984
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Thomas F. Lorenz		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Region VII 324 East 11th Street Kansas City, Missouri 64106		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-01-5995
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Region VII 324 East 11th Street Kansas City, Missouri 64106		13. TYPE OF REPORT AND PERIOD COVERED Draft EIS
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This draft environmental impact statement addresses the social, economic, and natural environmental impacts potentially resulting from implementation of the proposed comprehensive wastewater treatment facilities presented in the Draft Wastewater Facilities Plan for Greene County, prepared concurrently with this document. The Greene County planning area for these studies was divided into nine subareas, including the City of Springfield, seven outlying communities, and the remaining unincorporated area. For each subarea, a "no action" alternative and alternatives for new or modified conventional wastewater collection and treatment systems were evaluated, along with innovative and alternative systems, treatment plant processes, and alternative discharge points.

Impacts of the recommended alternatives were generally found to be beneficial, particularly to surface and ground water quality and efficient land use planning. Impacts associated with construction will include erosion, sedimentation, and limited damage to riparian habitats, and archaeological impacts will need to be mitigated. Cost impacts to residents in presently unsewered areas will be great, despite efforts to reduce them. Cost impacts for residents of the sewered areas of Springfield and Republic will be moderate. Four of the outlying communities propose to deliver wastewater to the City of Springfield. This regionalization was found to be environmentally and economically sound.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release unlimited.	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 455
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

☆ U.S. Government Printing Office: 1984—765-438/5130 Region No. 6

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VII
324 EAST ELEVENTH STREET
KANSAS CITY, MISSOURI - 64106

OFFICE OF
THE REGIONAL ADMINISTRATOR

TO: ALL INTERESTED AGENCIES, PUBLIC GROUPS AND CITIZENS

Attached is a copy of the Draft Environmental Impact Statement (EIS) for Proposed Wastewater Treatment Facilities, Greene County, Missouri. This document is submitted pursuant to Section 102(2)(c) of the National Environmental Policy Act of 1969 (Public Law 91-190). All comments on this draft EIS must be submitted to the Environmental Protection Agency (EPA) within 45 days after the Notice of Availability of this document is published in the Federal Register. The closing date for submitting comments is anticipated to be March 26, 1984. Additional copies of this document are available for public review at the following locations:

Springfield Main Library
397 East Central
Springfield, Missouri 65802

Republic Branch Library
135 South Highway 60
Republic, Missouri 65738

Greene County Building
and Planning Department
833 Boonville
Springfield, Missouri 65802

Hood-Rich Architects
and Consulting Engineers
801 South Glenstone
Springfield, Missouri 65802

Ash Grove Branch Library
101 East Main
Ash Grove, Missouri 65604

Please send your written comments to the attention of Edward Vest, Chief, Environmental Impact Section.

A public hearing on the draft EIS will be held in the Springfield Art Museum Auditorium at 7 p.m. on March 13, 1984. All interested parties are invited to attend and offer written or oral comments at this time.

Since the drafting of the EIS, the City of Republic, Missouri, has been withdrawn from the study. This action was taken at the request of the City, Greene County, Missouri Department of Natural Resources, and Missouri Clean Water Commission. The action was taken to expedite the construction of new wastewater treatment facilities at Republic and thus lessen the possibility of further groundwater contamination.

Additional information on this document or the review period may be obtained from Thomas Lorenz at (816) 374-5593 or FTS 758-5593.

Sincerely yours,

Morris Kay
Regional Administrator

i.a

DRAFT
ENVIRONMENTAL IMPACT STATEMENT
PROPOSED WASTEWATER TREATMENT FACILITIES
GREENE COUNTY, MISSOURI

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION VII, KANSAS CITY, MISSOURI

FEBRUARY 1984

APPROVED BY: Morris Kay, Regional Administrator

Consultants
Sverdrup & Parcel and Associates, Inc.
St. Louis, Missouri

SUMMARY

In 1979, the Greene County Sewer District received a grant from the U.S. Environmental Protection Agency (EPA) to initiate comprehensive wastewater facilities planning for the Greene County planning area.* This planning is intended to define wastewater collection, treatment, and disposal problems, identify alternatives for solving these problems, analyze the costs and environmental effects of each alternative, and select the optimal alternatives. Since wastewater management and disposal in Greene County may have critical impacts on sensitive and valuable natural and man-made environmental resources, and could increase costs to local residents, EPA initiated this Environmental Impact Statement (EIS) to examine those potential impacts as a concurrent part of the planning process.

The Greene County planning area includes most of Greene County and a small part of Christian County and is located in southwest Missouri. The planning area is within one of the Ozark plateaus and has gently rolling topography except for steeper terrain along the major streams.

The area is underlain by cherty carbonate rocks which are subject to solution activity. The resulting "karst" topography is characterized by sinkholes, caves, springs, losing streams, and an irregular bedrock surface. The planning area has many types of soils, but most of them have moderate to severe limitations for septic systems because of low soil permeability, shallow bedrock, high rock content, flooding potential, or proximity to sinkholes or other unfavorable geologic formations. Many of the soils in the area are classified as "prime farmland" by the Soil Conservation Service and, as such, are a valuable natural resource for agricultural productivity.

The planning area is divided between two drainage basins - the Osage River basin to the north and the White River basin to the south. The area's location on a drainage divide has important water resources and water quality implications. Since streams originate near divides, those in the planning area are small, limiting water supply resources and flows to assimilate pollutants.

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*The Greene County Sewer District was formed to sponsor wastewater facilities planning. Local plan approval and adoption, as well as facilities design, construction, and operation, remain the responsibilities of the individual municipalities in the planning area.

Ground water resources are comprised of a major (deep) aquifer and a minor (shallow) aquifer, separated by a formation that retards the movement of water between the two. The ground water and surface waters are closely connected. Streams recharge ground water during high flows, and the major streams are supplemented during drought periods by flows from springs. There are many "losing streams" in the area which naturally lose much of their flow into the ground water. Sinkholes and other recharge features also provide a direct connection between the surface and the upper aquifier.

The planning area occurs in the transition zone between the Ozark plateaus and the Osage plains. The Ozark plateaus possess the most diversified flora in Missouri. Within the broad transition zone, Ozark flora is dominant on the broken rocky ground along streams, while the prairie and plains flora occupies the more level and open sections of the uplands. Because of the diversified habitats found in the planning area, much of the wildlife that once occurred in either the Ozark plateaus or Osage plains has dispersed in both regions.

Many of the streams in the area are characteristic of very clear Ozark streams. Prairie streams are more turbid and most evident along the western edge of the area. While streams may be only a few miles apart by land, they can be hundreds or thousands of river miles apart. Thus, a fish in the Sac River in Greene County would have to swim over 1,500 miles to enter the James River in the same county. As a result, separate populations may slowly evolve into subspecies or separate species. The Niangua darter, Etheostoma nianguae, is restricted to the southern tributaries of the Osage River and is listed by the State of Missouri as RARE and is proposed for federal listing as THREATENED.

A distinctive feature of karst topography is the cave and the unique aspects of the cave environment appear in the species found in the deep interior. Cambarus setosus is a blind, white crayfish endemic to subterranean waters in southwestern Missouri. The Ozark cavefish, Amblyopsis rosae, is a blind cavefish that has been collected only from underground streams in southwestern Missouri and northwestern Arkansas. The blind cave salamander, Typhlotriton spelaeus, is a species unique to the Ozarks. The Ozark cavefish is listed as RARE by the State of Missouri and is proposed for federal listing as THREATENED. The cave crayfish, *Cambarus setosus*, is also on Missouri's list of rare and endangered species. Cave organisms are very sensitive to pollution or other changes in their stable environment.

Substantial numbers of prehistoric and historic archaeological sites have been found in Greene County. Most surveys have been along major rivers and streams, but a few surveys of upland divides and upper reaches of small streams have revealed a significant number of sites, particularly near sinks and springs. Prehistoric Indian artifacts and sites are likely to be found where there is a permanent water source. There are also sites where geological formations include stones used in tool making, and probably upland hunting and burial sites.

The City of Springfield, which is ringed by several smaller communities, dominates urban development in the planning area. The area is divided into nine subareas (Springfield, Battlefield, Brookline, Fair Grove, Republic, Strafford, Walnut Grove, Willard, and the Unincorporated Low-Growth area) for wastewater facilities planning purposes. The area has grown rapidly with much of the growth in the last ten years occurring to the south and southwest of Springfield. The surrounding subareas of Battlefield, Fair Grove, Republic, Strafford, and Willard are projected to more than double their 1980 population by the year 2005, and the population of the City of Springfield is projected to increase from about 133,000 to over 168,000. The total population of the planning area is projected to increase from about 188,000 in 1980 to nearly 292,000 in 2005. About 12.5 percent of the land in the study area is developed with the remaining undeveloped land in agricultural use or vacant. Residential and commercial growth will continue to decrease the amount of undeveloped land.

Community services (police and fire protection, schools, parks, hospitals, etc.) and transportation are generally adequate to serve the needs of the area. The City of Springfield depends primarily on surface water, supplemented with ground water, for its water supply. The surrounding communities and rural residents rely on ground water supplies. Securing future water supply sources and protecting existing sources to meet the needs of the mid-1990's and beyond is a very important concern of the City of Springfield.

There are three major municipal wastewater treatment plants in the planning area, serving mainly the incorporated areas of Springfield and Republic. A number of subdivisions, mobile home parks, and other developments have their own treatment systems, mainly lagoons and small treatment plants. The remaining population is served by on-site treatment facilities, mostly septic tank systems.

The existing Springfield Northwest Plant and the Republic plant have frequently failed to meet required effluent limitations. Renewal of the expired discharge permits for both plants has been denied because of the serious deficiencies. The plants are becoming overloaded and are not designed to meet the current limits. The lagoons used for part of the treatment at Republic represent a significant threat to ground and surface water quality from potential catastrophic collapse associated with sinkholes in the area. Springfield's Southwest Plant provides a high degree of treatment and generally meets effluent limitations. Excessive infiltration and inflow are serious problems for the Republic and Springfield systems, overloading collection and treatment facilities during wet weather.

Many of the small treatment systems are overloaded and poorly operated and maintained. These conditions limit the treatment effectiveness and often result in violations of effluent limitations. Soils and geological conditions have caused numerous problems of surfacing septic tank effluent and actual or potential ground water contamination.

The Draft Wastewater Facilities Plan for Greene County, the subject of this EIS, divided the planning area into nine subareas for study. For each subarea, a "no action" alternative and alternatives for new or modified wastewater collection and treatment systems were developed. The feasibility and costs of cluster systems and gravity, pressure, and vacuum sewer collection systems were assessed for unsewered areas, and treatment plant processes and alternative discharge points were evaluated. New collection facilities and improved wastewater treatment and management were considered for existing systems. The proposed improvements for each subarea are identified in the following list and Summary Figure.

Impacts of the recommended alternatives will generally be beneficial, particularly to surface and ground water quality and efficient land use planning. The proposed alternatives would replace or eliminate inadequate wastewater treatment plants and provide suitable collection and treatment systems at communities with serious problems of failing septic tank systems.

Some adverse impacts associated with the recommended alternatives will be relatively minor, and many will be of a short-term nature. These include the erosion, sedimentation, and damage to riparian habitat associated with sewer construction in stream corridors, and the traffic disruption, safety hazards, and noise caused by construction in urban areas. There are also significant potential adverse impacts that should be mitigated. These include measures to avoid or minimize the hazard of sewer line failure in sinkhole areas and avoid or minimize the effects of construction on archaeological resources.

Cost impacts of collection and treatment systems to residents of the unsewered subareas will be great, despite efforts to reduce costs and the potential for grant assistance. Officials and citizens of these communities have participated in the planning for these subareas and their views are generally reflected in the proposed plans. Cost impacts for residents of Springfield and Republic will be moderate.

Facilities planning and this EIS analysis were performed concurrently and in coordination to help prevent environmentally poor choices. This EIS analysis has found that the environmental benefits of the proposed alternatives outweigh the adverse environmental effects by a significant margin. EPA therefore intends to provide further federal funding for these projects, subject to all other review and approval requirements of EPA's Construction Grants Program, as well as the requirements of the Missouri Department of Natural Resources (MDNR).

FACILITIES PLAN RECOMMENDATIONS
BY SUBAREA

Springfield Subarea

- Conduct a sewer system evaluation survey to locate areas of excessive inflow and infiltration.

Southern System:

The following are proposed to eliminate existing small treatment facilities and pump stations and to serve presently unsewered development:

- Construct Pierson Creek interceptor, interceptor extension, and contributing lines to deliver wastes to the Southwest Treatment Plant via the existing James River interceptor.
- Construct the Thompson Branch trunk, pump station, and force main discharging to the James River interceptor; also several smaller lines discharging directly to the James River interceptor.
- Construct several lines connecting to the existing Ward Branch trunk.
- Construct several lines connecting to the Wilsons Creek interceptor; also a line and pump station discharging to the Southwest Plant interceptor.

Recommendations with regard to treatment are as follows:

- Conduct pilot studies of further sludge stabilization prior to land spreading.
- Incorporate sludge treatment and disposal studies into overall solid waste management.
- Consider industrial reuse of Southwest Treatment Plant effluent with future expansion of Springfield's Southwest Power Plant.
- Analysis at this time suggests the James River pump station and Southwest Treatment Plant should be expanded when needed in the 1990's rather than constructing a new James River treatment plant to treat James River interceptor waste flows.

FACILITIES PLAN RECOMMENDATIONS
BY SUBAREA (continued)

Northern System:

- Construct a new Northwest treatment plant at the Murray site, about three miles downstream.
- Construct the Little Sac River interceptor from the existing Northwest plant site to the new plant site.
- Construct the South Dry Sac interceptor.

Battlefield Subarea

- A collection sewer system within the city limits with pumping to Springfield's James River pump station and Southwest Treatment Plant.

Brookline Subarea

- A collection sewer system to serve much of the subarea with pumping to Springfield's Wilsons Creek interceptor and Southwest Treatment Plant.

Fair Grove Subarea

- A collection sewer system to serve most of the subarea and a treatment plant discharging to a tributary of the Pomme de Terre River.

Republic Subarea

- Collection system improvements within the city limits and replacing existing treatment facilities with a new plant nearby.

Strafford Subarea

- A collection system to serve most of the subarea with pumping to Springfield's southern system and Southwest Treatment Plant.

Walnut Grove Subarea

- A collection system and treatment plant is proposed; discharge to Sugar Creek is being reevaluated in light of recently determined losing stream constraints.

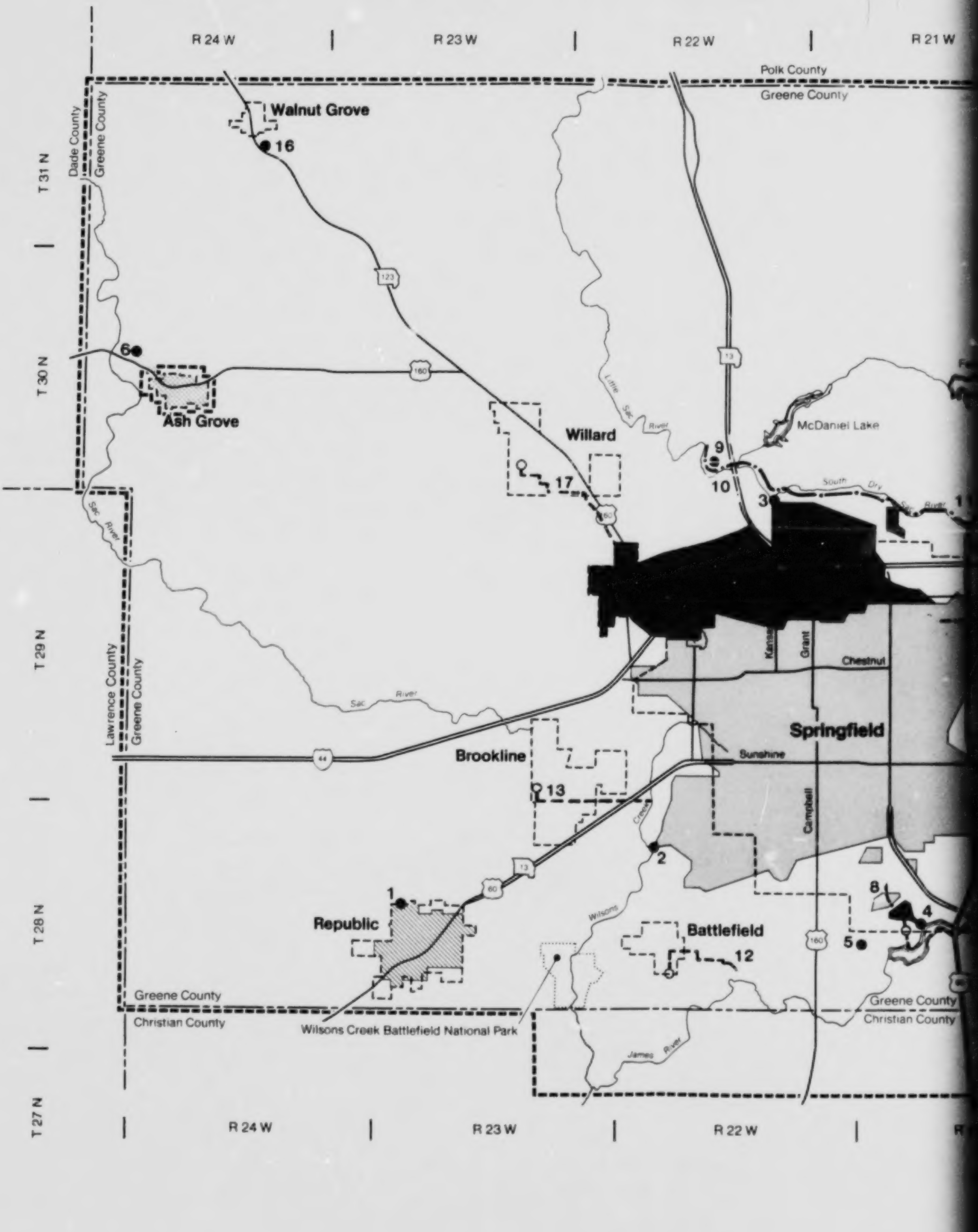
FACILITIES PLAN RECOMMENDATIONS BY SUBAREA (continued)

Willard Subarea

- A collection system to serve parts of the subarea with pumping to Springfield's Airport Branch trunk and the Northwest Treatment Plant.

Unincorporated Low Growth Subarea

- Criteria for improved on-site systems are suggested for adoption and program implementation.


R 24 W
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Polk County
Greene County
Dade County
Greene County
T 31 N
Walnut Grove
16
123
6
T 30 N
160
Ash Grove
Willard
17
Little Sac River
13
9
10
McDaniel Lake
3
South Dry Sac River
Sac River
T 29 N
Kansas
Grant
Chestnut
Lawrence County
Greene County
Sac River
Springfield
44
Brookline
Sunshine
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Campbell
Wilsons Creek
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Republic
Wilsons
Battlefield
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Greene County
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Wilsons Creek Battlefield National Park
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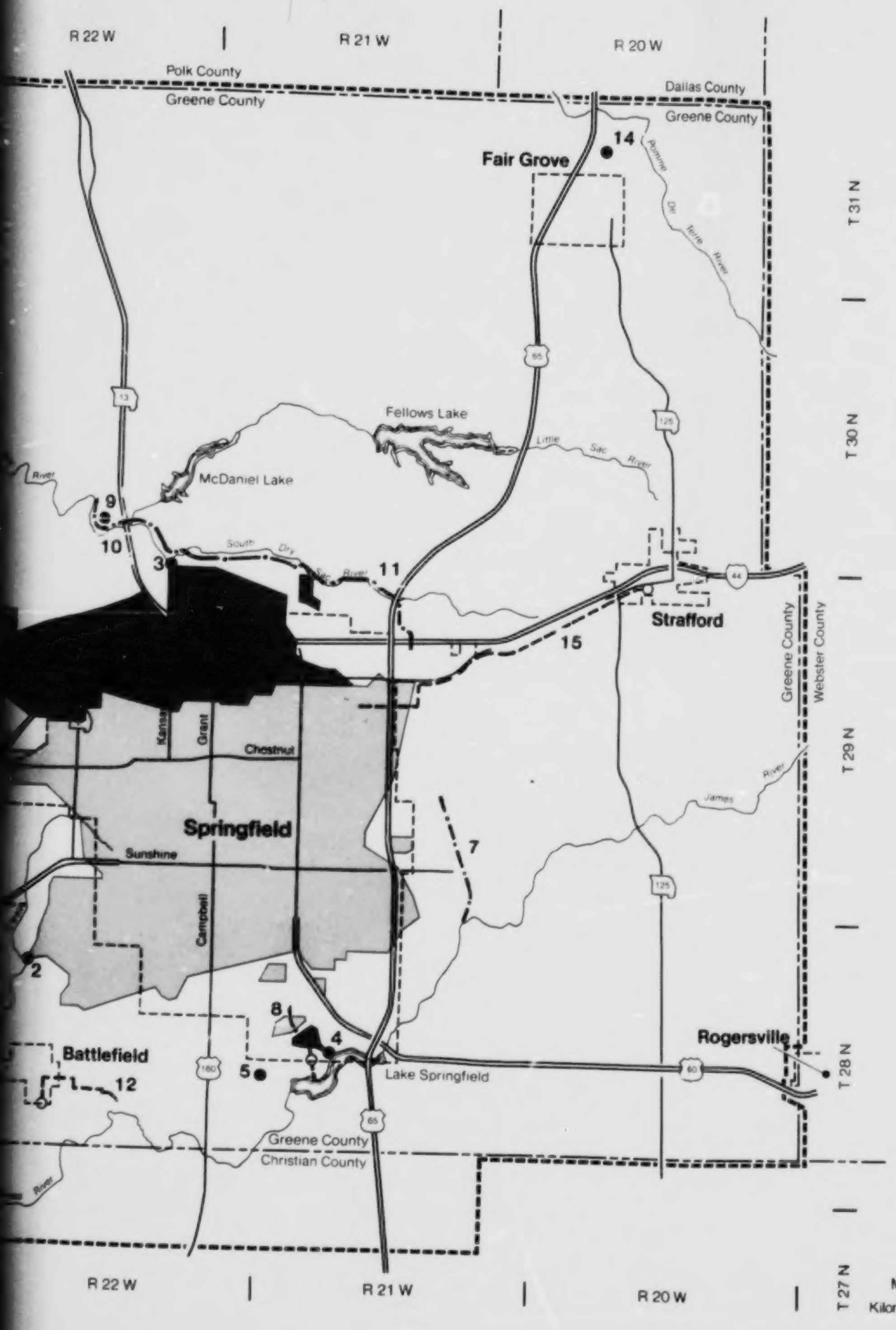

Existing and Proposed Public Wastewater Facilities

Summary

Legend

● Treatment Plant
○ Pump Station (P.S.)
---Force Main (F.M.)
-·-Interceptor

Existing Treatment Plants

1 Republic
2 Southwest
3 Northwest
4 Lakewood Subdivision
5 Sunburst Hills Subdivision
6 Ash Grove

Treatment Plant Service Area

░ Ash Grove
▨ Republic
▒ Southwest
■ Northwest
■ Lakewood Subdivision

Major Proposed Facilities

1 New Republic Plant

Springfield:
7 Pierson Creek Interceptor
8 Thompson Branch Interceptor
9 New Northwest Plant
10 Little Sac Interceptor
11 South Dry Sac Interceptor

12 Battlefield P.S./F.M.
13 Brookline P.S./F.M.
14 Fair Grove Plant
15 Strafford P.S./F.M.
16 Walnut Grove Plant
17 Willard P.S./F.M.

Planning Area ------
City Limits ------
County Limits --—-

Miles 1 2 3 4
Kilometer 1 2 3 4 5 6
North

17

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I. INTRODUCTION

A. BACKGROUND OF THE FACILITIES PLAN

The objective of the Clean Water Act of 1977 and the Water Pollution Control Act of 1972 is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." To achieve this objective, the Acts authorize the U.S. Environmental Protection Agency (EPA) to make grants to local governments to assist in paying the costs of planning, designing, and constructing wastewater treatment facilities.

During the facilities planning phase, referred to as "Step 1," the local government defines the wastewater problems it hopes to solve through facilities construction; identifies alternative means of solving the problems, including alternative wastewater collection and treatment systems; analyzes the costs and environmental effects of the alternatives; and chooses the most economically and environmentally sound alternatives. Following approval of the wastewater facilities plan by the state and completion of the design, the local government may apply for the Step 3 grant for construction, which includes a standard allowance for design (formerly Step 2). Small communities may apply for a combined Step 2+3 grant, including a design allowance, upon approval of the facilities plan. Funding for all steps is dependent upon the priority assigned to the project by the state relative to other projects in the state.

The Greene County Sewer District was formed in 1977, and in 1979 received a Step 1 grant from EPA under Section 201 of the Water Pollution Control Act to initiate comprehensive wastewater facilities planning for the Greene County area. The facilities planning area covers all of Greene County except for Ash Grove and Rogersville, plus 26 square miles in north central Christian County (see Figure 1). Ash Grove has a suitable treatment facility, and the City of Rogersville, which is mostly in Webster County, is developing its own facilities plan.

The District retained Hood-Rich, an engineering and architectural consulting firm located in Springfield, to prepare the facilities plan and to coordinate public participation in the planning process. The planning area is divided into the Springfield, Battlefield, Brookline, Fair Grove, Republic, Strafford, Walnut Grove, Willard, and Unincorporated Low-Growth subareas for analysis. In July 1983, Hood-Rich completed a Draft Wastewater Facilities Plan for Greene County Sewer District, prepared concurrently and in coordination with this EIS (1)*. The Facilities Plan recommends specific collection and treatment facilities for implementation over the next 20 years for each planning subarea.

The Greene County Sewer District was formed to sponsor and coordinate wastewater facilities planning. Local approval and adoption of the respective plan elements, as well as facilities design, construction, and operation, remain the responsibilities of the individual municipalities or other local political jurisdictions.

B. BACKGROUND OF THE EIS

The National Environmental Policy Act of 1969 requires that the federal government prepare an Environmental Impact Statement (EIS) for any major federal action that could significantly affect the environment. Approving the Greene County Facilities Plan and the subsequent design and construction grants would constitute such an action because of the scope of the plan and the cost that may be involved; because new and expanded sewer service may affect the pattern and rate of development, which could cause adverse community impacts; and because of the sensitive interaction between the area's ground water and surface water resources that may be affected by proposed facilities. EPA therefore issued a notice of intent to prepare this EIS on the Greene County Facilities Plan and retained Sverdrup & Parcel and Associates, Inc., as a consultant.

The purpose of this EIS is to provide federal, state, and local decision makers and the concerned public with sufficient information on the environmental, economic, and technical impacts of the

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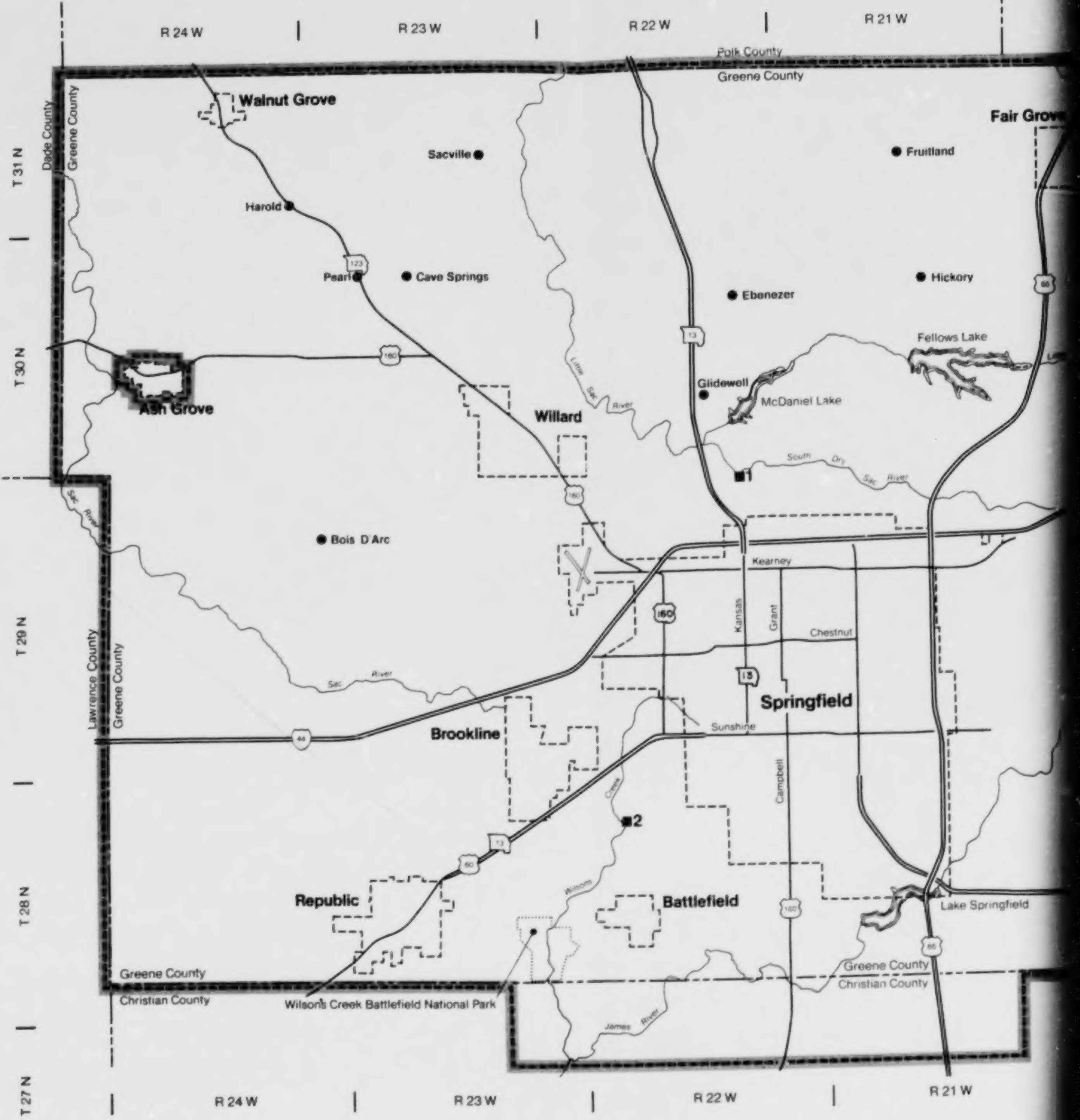
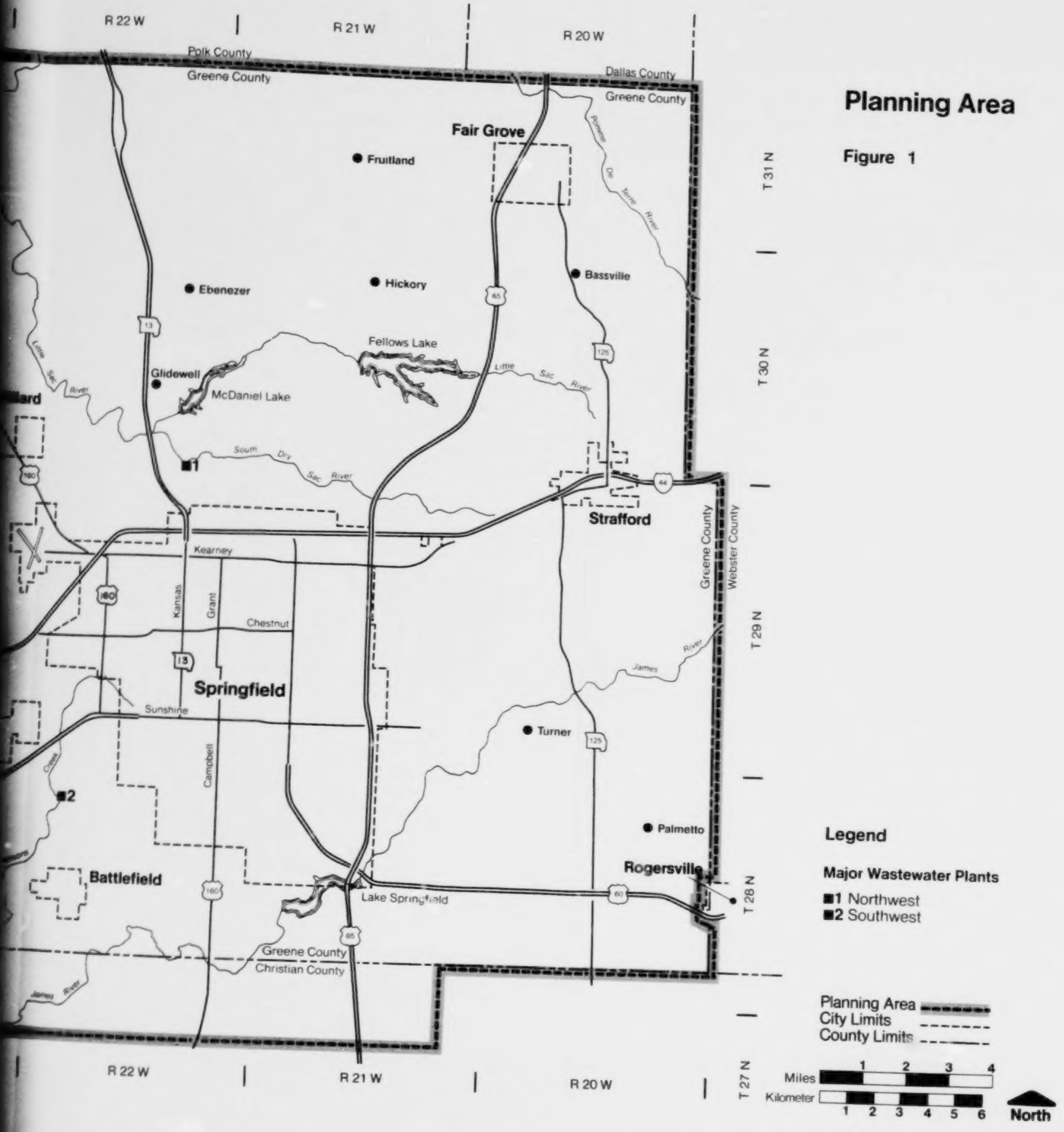
*Numbers in parentheses denote references listed at the end of this document.


R 24 W
R 23 W
R 22 W
R 21 W
Polk County
Greene County
Dade County
Greene County
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
Walnut Grove
Sacville
Fruitland
Fair Grove
Harold
123
Pearl
Cave Springs
Ebenezer
Hickory
65
13
160
Fellows Lake
Glidewell
McDaniel Lake
Little Sac River
Ash Grove
Willard
South Dry Sac River
1
Sac River
Bois D'Arc
Kearney
160
Kansas
Grant
Chestnut
13
Lawrence County
Greene County
Sac River
Springfield
Sunshine
44
Brookline
Campbell
Creek
2
13
60
Wilsons
Republic
Battlefield
160
Lake Springfield
65
Greene County
Christian County
Greene County
Christian County
Wilson's Creek Battlefield National Park
James River
R 24 W
R 23 W
R 22 W
R 21 W

Planning Area

Figure 1



various alternatives to make sound wastewater management decisions. This EIS also presents the conditions which EPA will place on further federal grants for the design and construction of the proposed facilities. These grant conditions are to ensure that all construction resulting from these grants is in conformance with federal policies for protection of the environment.

To save time and allow better coordination among the involved parties, the EIS and Facilities Plan were prepared simultaneously. EIS preparation consists of two major phases: (1) collection and analysis of information on the existing environment that may generally be affected by wastewater facilities and (2) comparative assessment of specific wastewater management alternatives on the basis of their environmental impacts. An Environmental Setting Report, the result\of the first phase of EIS preparation, was distributed in January 1981 to aid in the planning. Hood-Rich then prepared population projections for each of the planning subareas in Greene County, and identified specific wastewater management alternatives and costs. The second phase of EIS preparation began when the alternatives identification and cost-effectiveness information was available. The Setting Report was updated and used for the environmental evaluation of alternatives to produce this Draft EIS, which is being circulated among interested agencies and citizens for review and comment. The Draft will be revised accordingly and a Final EIS will be published.

C. MAJOR ISSUES OF THE EIS

In the course of the preparation and review of the Environmental Setting Report and Facilities Plan alternatives for Greene County,* it became clear that the EIS should focus on several major issues. These issues are briefly presented as follows:

1. Direct Effects on Sensitive Environmental Features

A principal concern of the EIS is the determination of the primary impacts on the sensitive environmental features of the Greene County planning area, such as floodplains, sinkholes, losing streams,

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* EIS scoping meetings were held in 1980 and a questionnaire on issues was distributed. Comments were also received on the Environmental Setting Report.

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wetlands, forests, prime farmlands, undisturbed prairie, rare and endangered species, historic and prehistoric sites, and drinking water supplies.

2. Induced Development in Outlying Areas

In many instances across the country, the provision of sewerage facilities in previously unsewered areas has led to increased residential and commercial development. In order to encourage efficient patterns of development, sewerage facilities planning should be coordinated with plans for the provision of transportation, schools, and other necessary community services and utilities. The EIS must examine the compatibility of the sewerage facilities plan with the other growth management plans of the area.

3. Effects of Inadequate Treatment and Sewer System Inflow and Infiltration

Some treatment plants in the area are overloaded, poorly operated, or not designed to meet current treatment requirements. Overflow of sanitary sewers and treatment plant by-passing during wet weather is a significant problem at existing central collection and treatment systems

4. Pollution from Failing Septic Tank Systems

The extent to which the Facilities Plan proposals eliminate the public health and water quality problems associated with failing septic tank systems will be addressed in the EIS. Most of the smaller communities in the planning area are unsewered and serious septic tank effluent surfacing and ground water pollution problems have been experienced.

5. Economic Impact of the Proposed Projects

A very significant impact of the proposed projects will be the costs to local residents. This issue has been voiced during the course of the Facilities Plan public participation program. This document will discuss the magnitude and distribution of the costs, the possible methods of assessment, and the possible effects of those charges on the local community including the owners of agricultural and undeveloped land.

D. ORGANIZATION OF THIS DOCUMENT

Following this chapter, the updated general description of the existing environmental setting of the Greene County planning area is given in Section II. The specific wastewater management alternatives considered in the Facilities Plan for each of the planning subareas are presented in Section III, along with an indication of the alternative proposed for implementation. Section IV presents the types of impacts that may occur to areas of the natural and man-made environments from various wastewater management alternatives, along with some measures that can be used to reduce these adverse effects. Section V contains a summary of the analysis of the specific impacts of each of the alternatives for the individual subareas, and Section VI focuses on those impacts felt to be most significant. Section VI also presents the alternatives preferred by EPA, and specific federal grant conditions judged necessary to provide an environmentally sound wastewater management solution.

II. ENVIRONMENTAL SETTING

This chapter describes the baseline physical, biological, and socioeconomic conditions in the planning area to help understand and measure the impacts of proposed project actions and alternatives. Environmental aspects relevant to the identified issues are emphasized. Information presented in this chapter was gathered during the latter half of 1980 and updated in 1983.

A. GEOLOGY AND SOILS

1. Physiography and Topography

a. Physiography. The planning area is situated in and representative of the Springfield Plateau, one of the Ozark plateaus within the Interior Highlands physiographic division (see Figure 2). The Springfield Plateau is on the western slope of the regional Ozark dome structure whose crest is the St. Francois Mountains. This plateau is separated from the Salem Plateau to the east by the east-facing Eureka Springs Escarpment, which crosses the northeast part of Greene County in a northwest-southeast direction (3). The planning area has gently rolling topography with low relief, except along the major streams.

b. Karst Topography. The planning area is underlain by cherty limestones and dolomites (3). These carbonate rocks, especially those with coarser crystalline structure, have been extensively dissolved by downward-percolating water that is actually very dilute carbonic acid. This acid originates from atmospheric carbon dioxide absorbed by rainfall, from decaying surface vegetation, and from shales with acid leachate. The cracks, joints, fissures, bedding planes, and chert beds in the bedrock facilitate penetration by the mildly acid water percolating underground, permitting it to cut crevices, solution channels, caverns, and cave passages. This solution activity results in a topography referred to as "karst."

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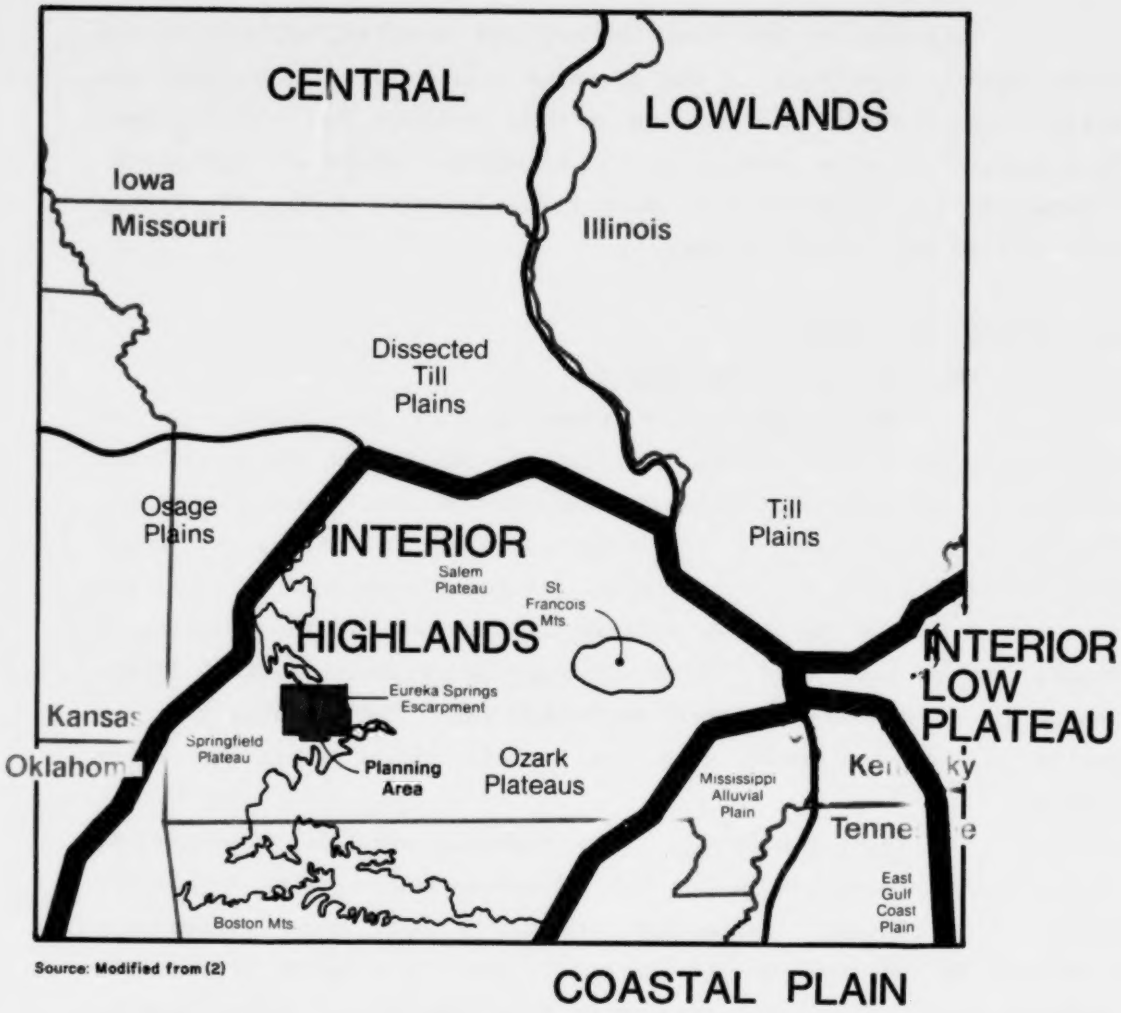
Regional Physiography

Figure 2



Source: Modified from (2)

Karst topography is characterized by sinkholes and related collapse structures, caves, springs, losing streams, and an irregular bedrock surface of "cutters" and "pinnacles" (see Figure 3). These cutters and pinnacles are solution crevices and isolated pillars of rock, commonly marked by 10 to 15 feet of relief in the bedrock surface (4). All of these features have a direct bearing on the planning of wastewater treatment facilities in the planning area.

1) Sinkholes. Sinkholes are depressions formed either by solution of surficial carbonate rock or by collapse of a cave roof. They are generally basinlike or funnel-shaped. Sinkholes formed by surficial solution usually do not contain bedrock fragments, whereas those formed by collapse do. Sinkholes or other openings through which water, soil, and other materials can enter bedrock formations are called "swallow holes." The City of Springfield and other communities use these swallow holes for storm drainage. Within Springfield's corporate limits, 195 sinkholes have been identified (3).

2) Caves. Cave formation begins when mildly acid water dissolves limestone and dolomite bedrock below the ground water table. Subsequently, the strata containing the drainage paths are uplifted and the ground water table is lowered, allowing dripping mineral-laden surface waters to form stalagmites and other deposits on cave surfaces (4). Enlargement of existing openings in the bedrock by frictional water erosion or other mechanical forces is not a factor in cave formation.

There are some 235 caves in Greene County (3). Maps for 89 of these are on file with the Missouri Geological Survey. The largest are Crystal Cave, near the Route H crossing of the Little Sac River; Doling Park Cave, west of U.S. 65, near the city limits; Fantastic Caverns, west of Highway 13, near the Little Sac River; and Sequiota Cave, on Lone Pine Road (6) (see Figure 6). Crystal Cave and Fantastic Caverns are operated commercially as tourist attractions. Fantastic Caverns was identified in 1979 by the U.S. Heritage Conservation and Recreation Service as a potential national natural landmark (7). The cave is a habitat for three species of animals on the Missouri list of rare and endangered species.

Christian County caves in the planning area are Fitzpatrick Cave, east of Highway 160, and Shelf Cave, north of Highway AA.

3) Springs. The Salem and Springfield plateaus contain the world's greatest concentration of springs, as well as some of the largest. Most of the Ozark area springs are outlets of subterranean streams that have been intersected by erosional valleys. As a result, most of the large springs are found at or near the valley floors of the principal streams. There are several types of springs, but seepage and fracture springs are the predominant types found in the planning area. Seepage springs usually discharge from numerous small openings in permeable material. Fracture springs usually flow from large openings in the rocks such as joints, fractures, caves, or faults.

4) Losing Streams. Surface streams intersecting sinkholes, caverns, or other subterranean openings where subsurface drainage takes place may lose part or all of their flow to underground channels; this underground flow may later reappear at the surface. These "losing streams" are discussed further in Sections II-B and II-C.

c. Elevations. The highest surface elevation in the planning area is 1518 feet above mean sea level and is located northeast of Springfield, east of U.S. 65 and south of Bassville. The lowest elevation in the area is about 905 feet above mean sea level, at the point where the Sac River leaves Greene County northwest of Springfield. The maximum relief is thus about 613 feet (3, 11).

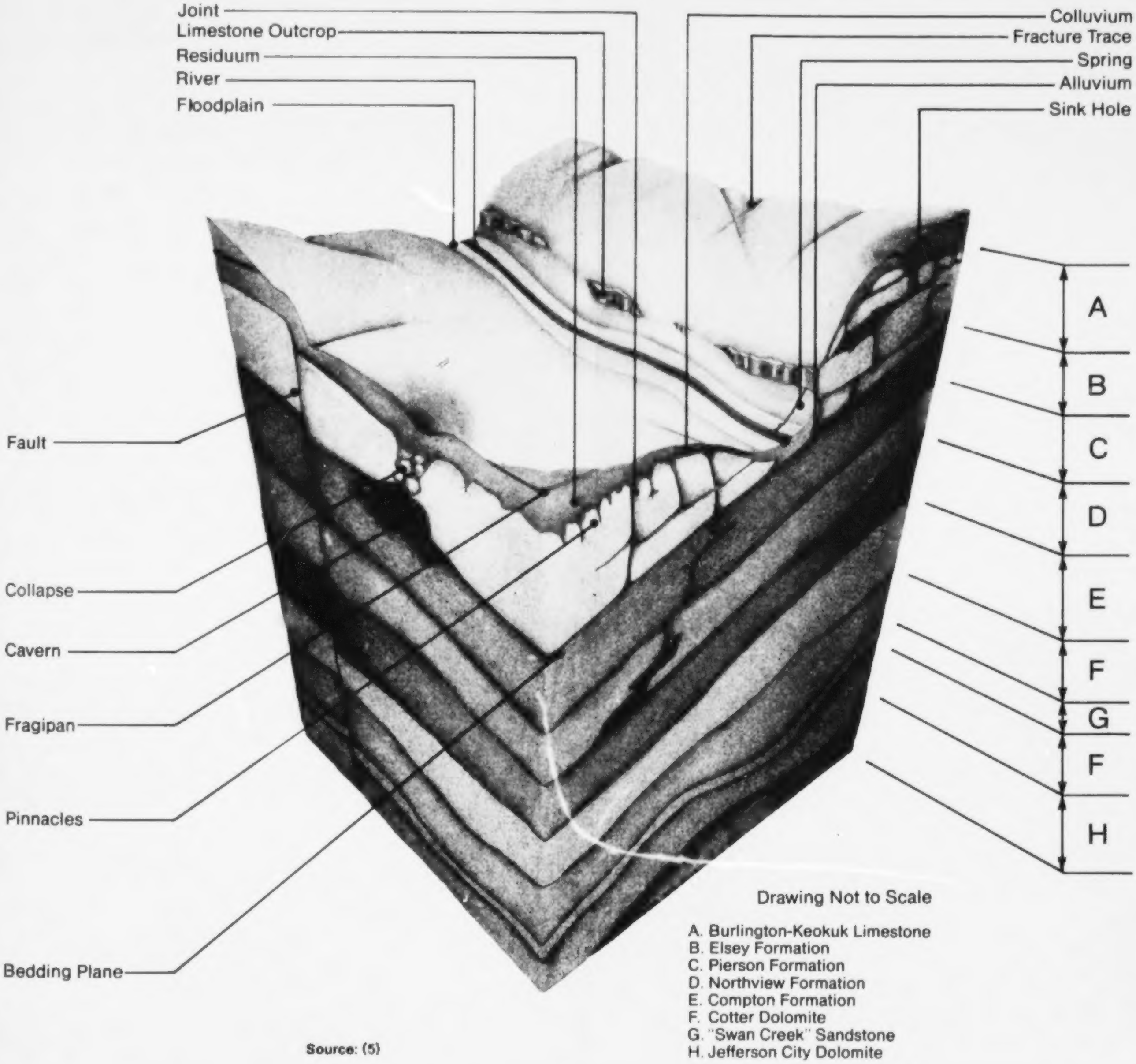
2. Areal Geology

Rock formations outcropping in the area range from the Roubidoux sandstone and the Cotter Dolomite of Ordovician Age (oldest) up to the Warner formation of Pennsylvanian Age (youngest). A generalized geologic column for the planning area is shown by Figure 4. The Swan Creek sandstone is an important water-bearing formation (or "aquifer"). The Northview is a confining layer separating the "upper" and "lower" aquifers, which are each actually composed of several water-bearing formations.

Appendix A - Section 1 provides brief stratigraphic descriptions of outcropping formations in the planning area (13, 14).

Figure 3

Generalized Surface-Subsurface Relationship



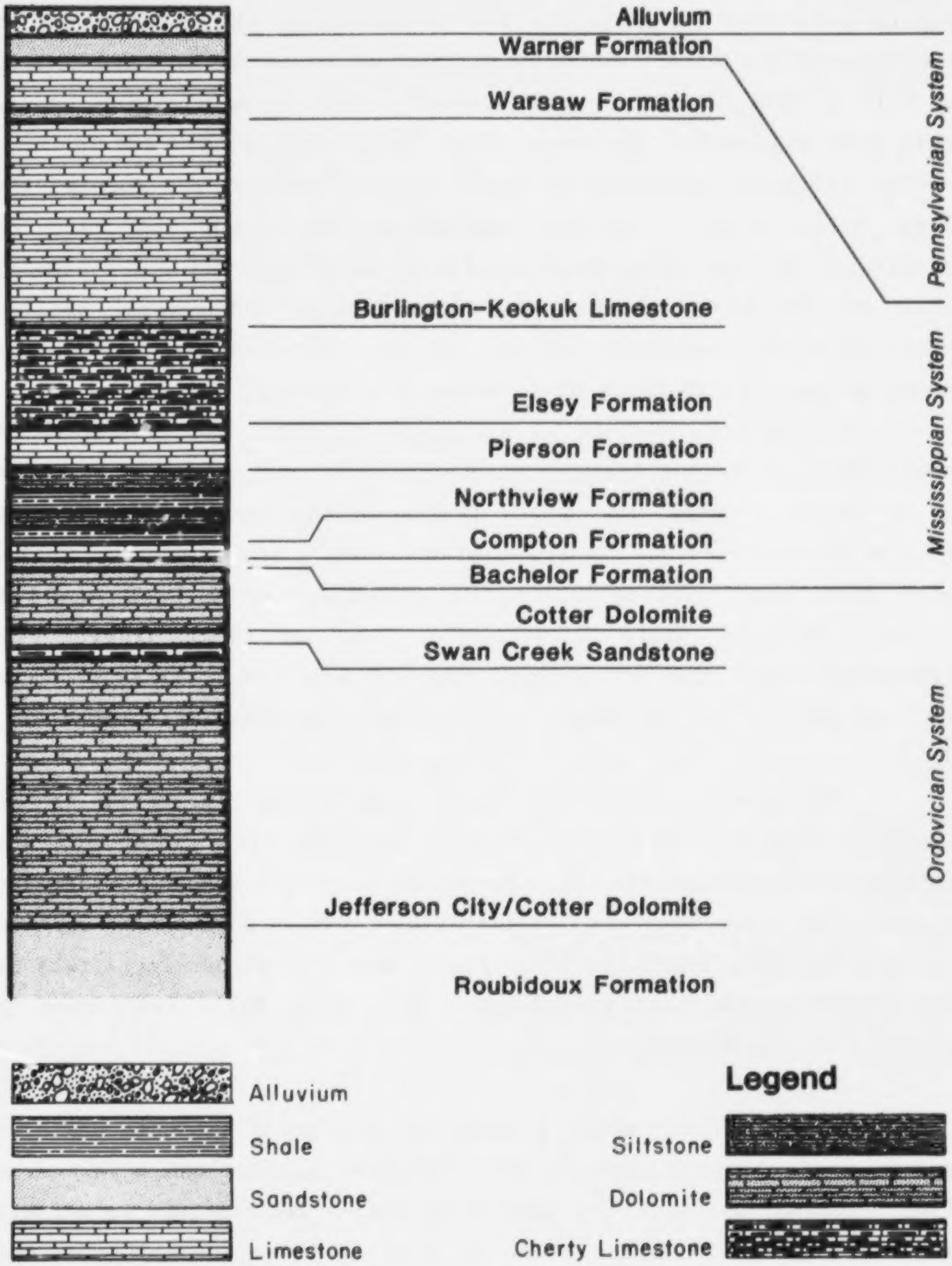
Drawing Not to Scale

A. Burlington-Keokuk Limestone
B. Elsey Formation
C. Pierson Formation
D. Northview Formation
E. Compton Formation
F. Cotter Dolomite
G. "Swan Creek" Sandstone
H. Jefferson City Dolomite

Source: (5)

Generalized Geologic Column

Figure 4



Source: (14)

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3. Structural Geology

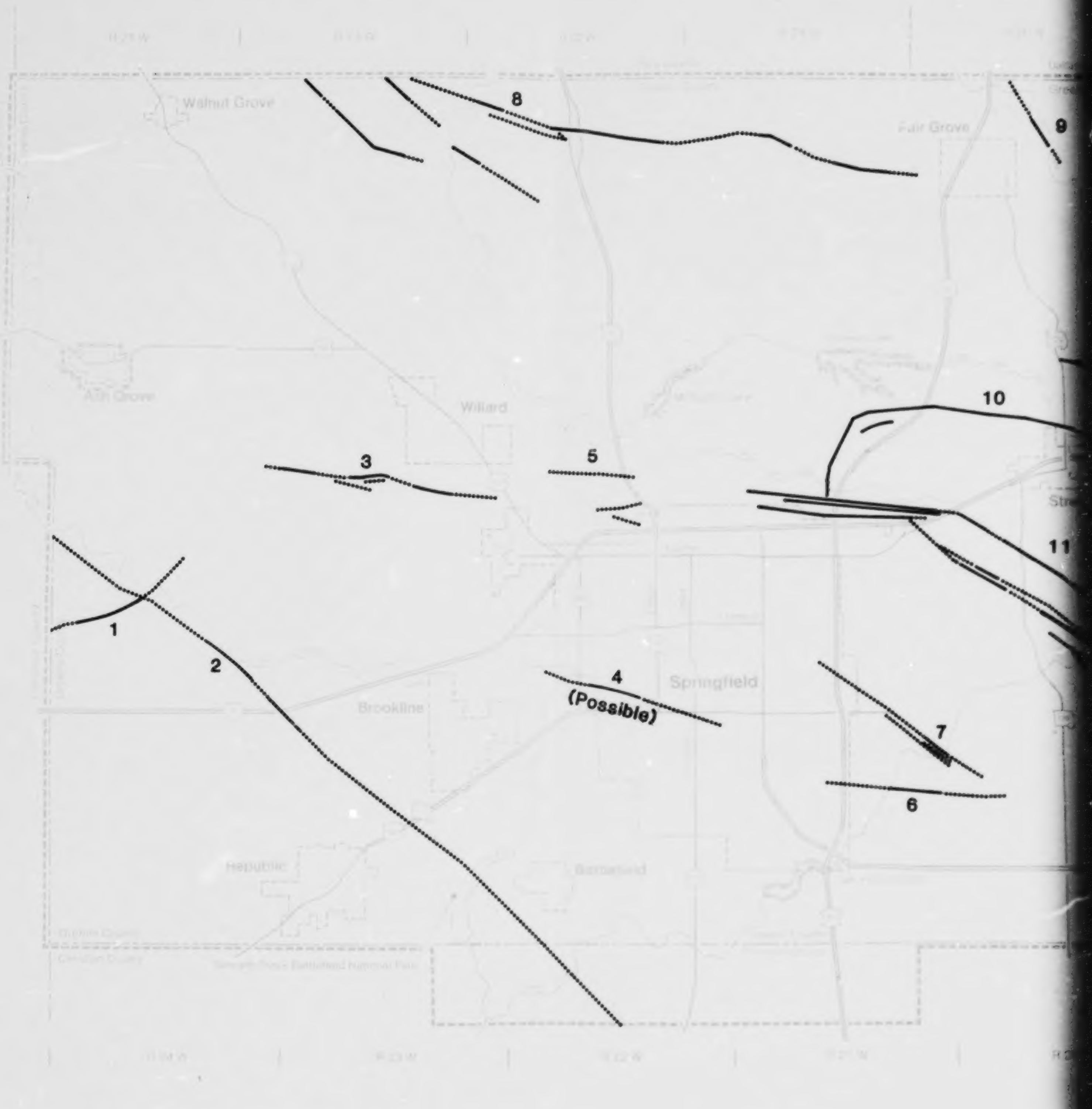
The regional dip of bedrock strata, modified locally by slight flexures and faulting, is to the west-southwest of the Ozark uplift at about 40 feet per mile. Locally, the dip may be to the west-northwest. The bedrock has been broken by several fault zones crossing Greene County (see Figure 5). The major fault zones are the Graydon Springs, trending northwest-southeast in the northeast part of the county; the Valley Mills zones, trending east-west just north and east of Springfield; the Sac River-Republic fault, trending northwest-southeast across the southwest quarter of Greene County; and several smaller faults which may represent offset and parallel parts of the larger systems or isolated ruptures of folded structures (12, 15).

Lineaments, visible on aerial photographs, are indicative of structurally controlled features such as faults and joints. They also may, at least in part, be due to faults in the Precambrian basement rock, below the bedrock faults listed above. Lineaments in Greene County have been plotted under the direction of K. C. Thomson of Southwest Missouri State University. Some of these lines trend northwest-southeast and are aligned with the major fault systems of the area. Another set of lineaments trends roughly northeast-southwest (12, 16).

The structural displacements may affect the planning of wastewater treatment facilities in the planning area. Displacements breaching the confining Northview Formation provide a connection between the upper and lower aquifers, facilitating downward movement of surface pollution into the lower aquifer. Faults may also either facilitate or block lateral movement of groundwater. The Valley Mills fault zone is an example of the former.

4. Seismology

Structural movement, closing or opening of sinkhole drainage channels, and pipeline rupture and consequent leakage can result from seismic events. All parts of the United States are assigned to seismic risk zones on an increasing scale of zero to three, depending on the



Walnut Grove
8
9
Fair Grove
Ash Grove
Willard
10
3
5
11
1
2
4
(Possible)
Springfield
Brookline
7
6
Republic
Battlefield
Greene County
Christian County
Wilson's Creek Battlefield National Park

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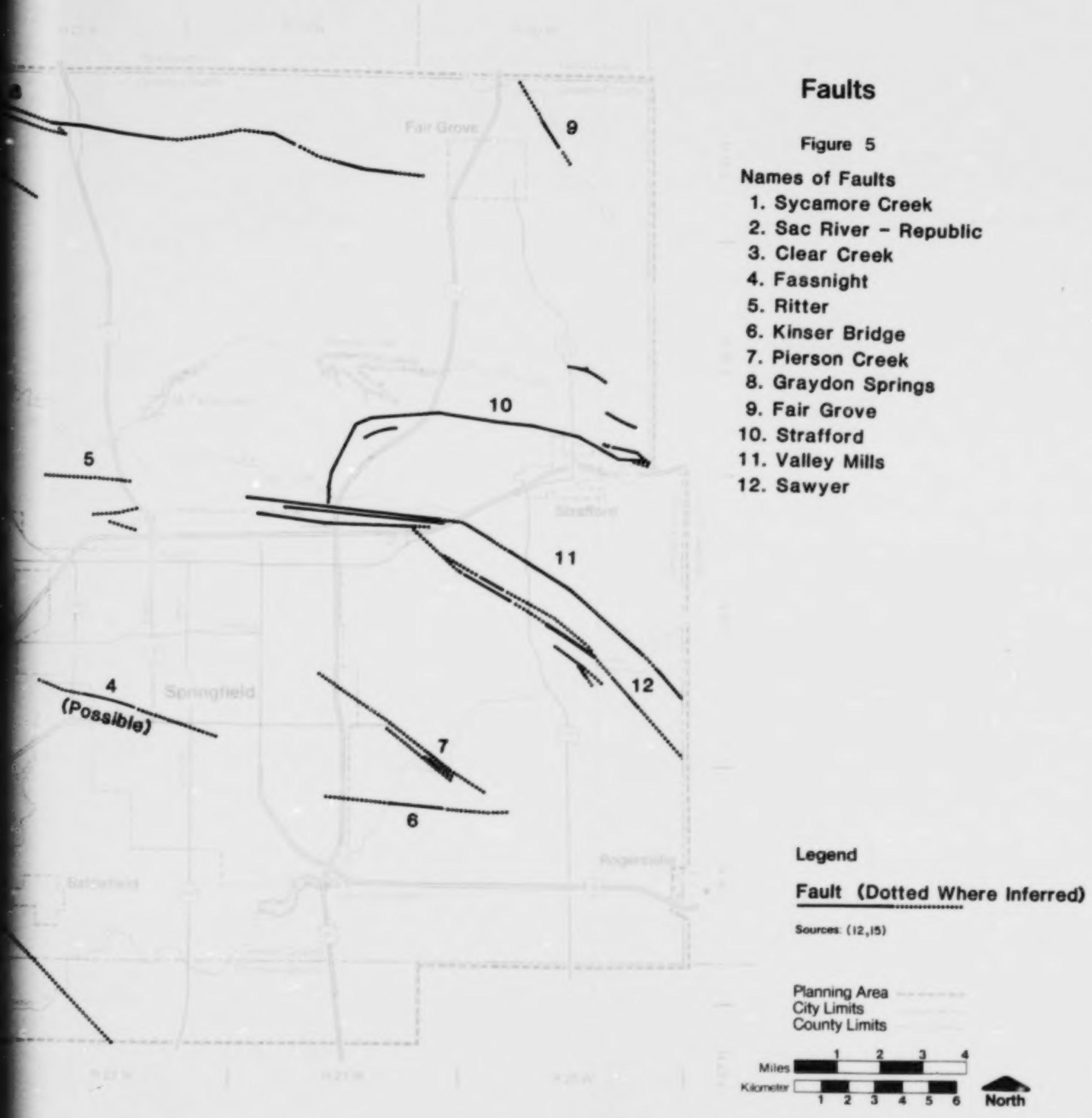

Faults

Figure 5

Names of Faults
1. Sycamore Creek
2. Sac River - Republic
3. Clear Creek
4. Fassnight
5. Ritter
6. Kinser Bridge
7. Pierson Creek
8. Graydon Springs
9. Fair Grove
10. Strafford
11. Valley Mills
12. Sawyer

Legend

Fault (Dotted Where Inferred)

Sources: (12,15)

Planning Area
City Limits
County Limits

level of earthquake damage that can be expected. The planning area is in Seismic Risk Zone 1. This means that minor earthquake damage can be expected. (Most of Missouri's earthquake activity has been concentrated in the southeast corner of the state, which lies within the New Madrid Seismic Zone.) Three earthquake epicenters have been recorded within 50 miles of Springfield (17). On February 21, 1885, an earthquake with a Modified Mercalli* (MM) intensity of III was centered in Jasper County. Two epicenters with an intensity of V have been recorded, one on January 3, 1901, in Dade County and the other on February 8, 1950, in Laclede County. Other earthquakes originating at greater distances (even outside of Missouri) have been felt in the planning area. The ground acceleration that has a 90% probability of not being exceeded within the next 50 years is less than 0.1g (amplitude of 1 inch and a frequency of 1 cycle per second) for the planning area.

5. Mineral Resources

Mineral resources in the planning area that have commercial value are limited to crushed limestone. Active and inactive quarries are shown on Figure 6.

Lead and zinc prospect pits and shafts are found near the junction of Pierson Creek and the James River. These date from around the turn of the century and are long abandoned. The formations mined included the Northview, Compton, and Cotter, which are located in the lower aquifer. Thus, the mine shafts provide a direct connection between surface water and the upper and lower aquifers.

6. Engineering Problems

Geologic features influencing design of wastewater treatment facilities in Greene County include slopes, sinkholes, soils, caves, faults and lineaments, mines, shale, chert, and pinnacles. The ways that these factors affect septic system design, installation, and performance are discussed in Section II-A-8. An overview of effects relating to other wastewater facilities is covered below.

---

* A scale of earthquake intensity increasing from Roman numeral I to XII.

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a. Slopes. Steep slopes are most common adjacent to portions of the major streams, i.e., the Pomme de Terre, Sac, and James rivers, and some of their tributaries. Soil cover is thin or absent on these slopes. Constructon of lagoons and other treatment facilities on steep slopes is difficult.

b. Sinkholes. Sinkholes are prevalent in the planning area, with about 20 to 30 percent of Greene County draining into sinks (20). Sinkhole areas are not suitable for septic systems, and examination of specific sites prior to construction is important. Springfield experiences an annual average of seven to nine surface collapses (21).

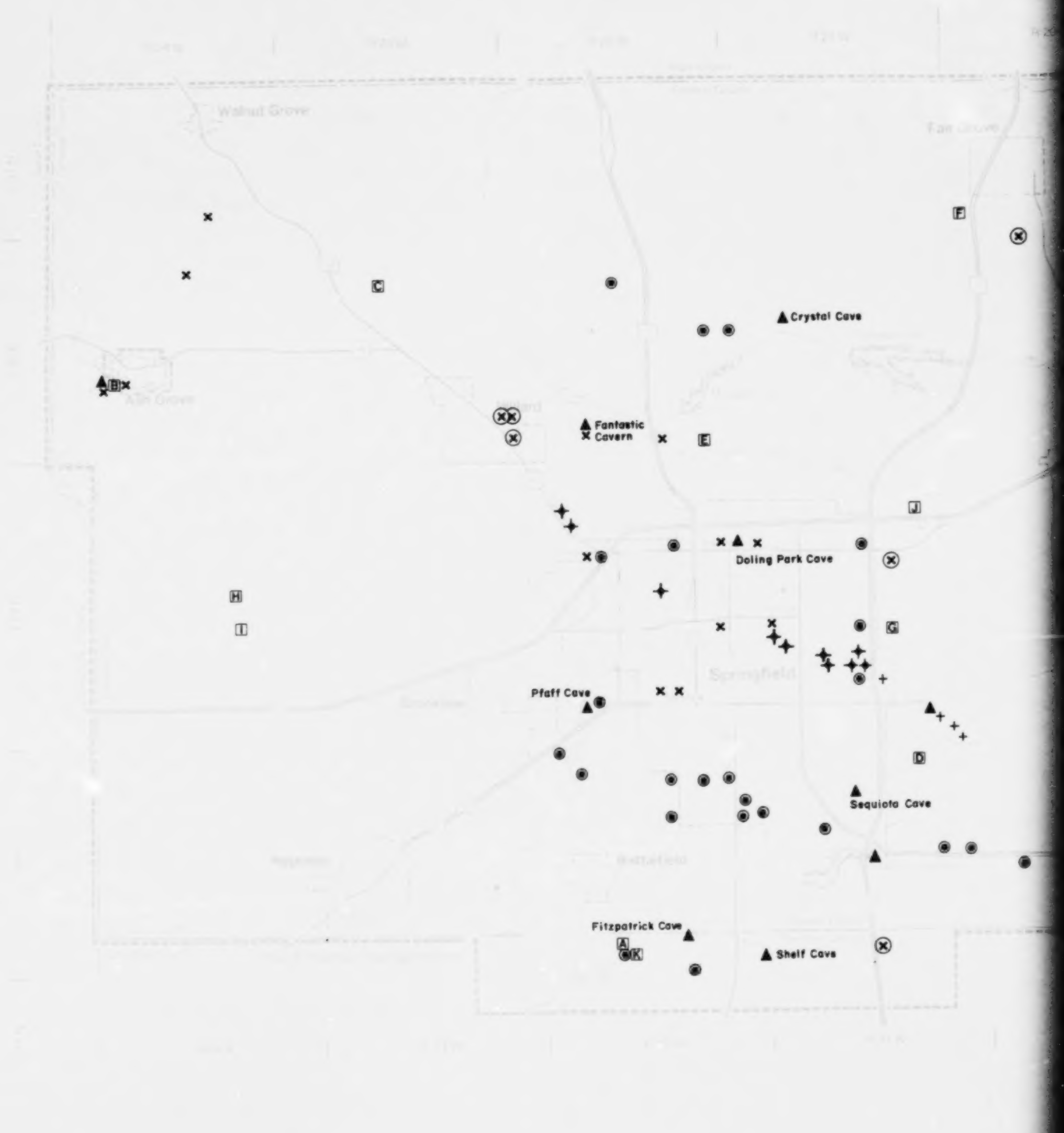
c. Soils. Residual soil is formed from the weathering of bedrock. Most of the soils on the uplands of the planning area are thick, red, clayey, and permeable residuum weathered from cherty limestone.

Some of the soils in the area present engineering problems. Several of the clays shrink and swell when subjected to moisture changes. Slopes or embankments may require special design for stability. Soil bearing capacity (ability to support a load) varies among soils and because of differential compaction on the highly irregular bedrock surface. This may cause uneven settlement of structures.

Permeability of soil is an important factor in sewage lagoons design and construction. Some soils contain a dense layer with low permeability called a "fragipan." Water percolating downward is blocked by the fragipan and flows along its surface until an opening in the fragipan layer is encountered. Where residual soil has very low permeability, septic systems do not function properly. A structure whose foundation penetrates the fragipan is likely to have drainage problems unless diversion structures, drains, or pumps are installed.

Where soil is too thin, septic systems and sewage lagoons may not be suitable. Expensive bedrock excavation may be required for major facilities in areas of thin soil cover.

d. Caves. Construction over a shallow cave may cause the ground surface to collapse. Filling a cave could disrupt subsurface drainage systems.


Walnut Grove
Fair Grove
F
C
Crystal Cave
B
Ash Grove
Willard
Fantastic Cavern
E
J
Doling Park Cave
H
I
G
Springfield
Pfaff Cave
Brookline
D
Sequiota Cave
Republic
Battlefield
Fitzpatrick Cave
A
K
Shelf Cave

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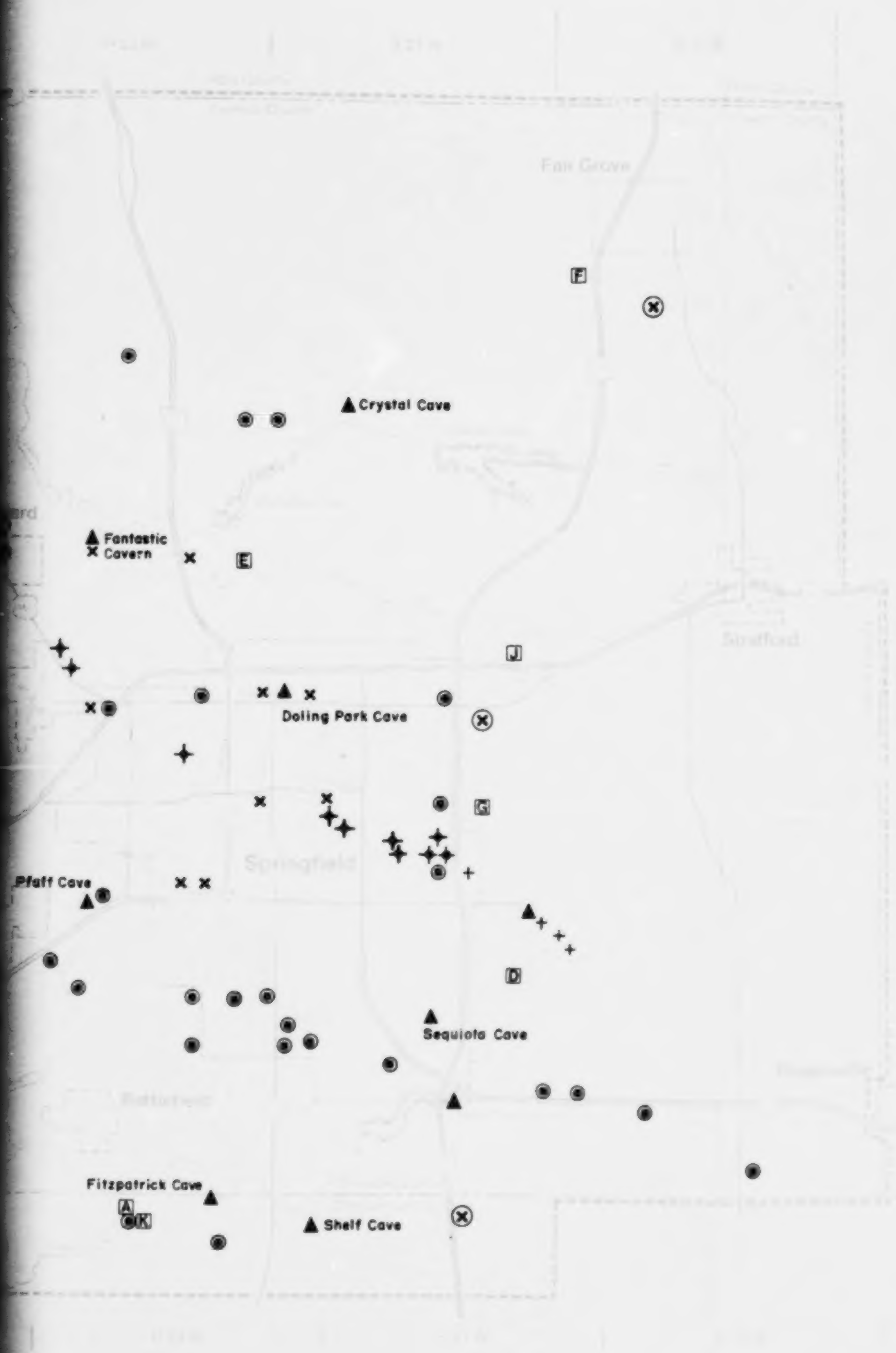
Unusual Geological Features, Swallow Holes, Caves, And Extractive Operations

Figure 6



Legend

- □ Unusual Geologic Feature (see text)
- ◉ Swallow Hole
- ✦ Sinkhole With Drainage Structure
- ▲ Cave
- ⊗ Active Quarry
- × Abandoned Quarry
- + Abandoned Mine

Sources: (3,6,18,19,23)

Planning Area
City Limits
County Limits

Miles 1 2 3 4
Kilometer 1 2 3 4 5 6
North

e. Faults and Joints. Fault zones and joints may provide direct connections to ground water, act as storm-water conduits, and be enlarged by solution.

f. Mines. Construction over or around mined areas should not be attempted without a thorough examination of the area, because collapse of underground workings might occur (22).

g. Shale. Steep slopes in shale formations are subject to failure by sliding. Shale is near the surface in the northeast part of Greene County.

h. Chert. An abundance of chert in the Elsey and Burlington formations makes excavation in these formations more difficult and more expensive because its hardness increases equipment wear. Where the limestone has been totally dissolved, the residual soil may consist of chert. Water moves easily through this fragmented material.

i. Pinnacles. Pinnacles resulting from the dissolving of limestone, particularly the Burlington formation, cause several problems. Unevenly dissolved bedrock results in elevation differences of as much as 15 feet or more within a distance of 3 ft horizontally. Pinnacles that have become detached and surrounded by clay complicate attempts to determine bedrock depth by probing. Estimating excavation quantities by conventional methods in these areas can be erroneous. Irregular bedrock surfaces may require excavation by hand. To provide even surfaces it may be necessary to remove pinnacles by blasting or to fill areas between pinnacles with concrete.

7. Unusual Geologic Features

Appendix A - Section 2 provides brief descriptions of unusual geologic features to be found in the planning area (see Figure 6). The most noteworthy as listed by the Missouri Division of Geology and Land Survey (23) include the following:

a. Blue Spring Natural Tunnel
b. Ash Grove Natural Tunnel
c. Cave Spring Natural Bridge
d. Crighton Natural Bridge

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e. Dry Sac Lost Hill Area

f. Fair Grove Mound

g. Mill Street Natural Bridge and Cave

h. Stonebridge (Mobley Natural Bridge and Springs)

i. Shaking Mound Spring

j. Valley Water Mills Fault Block

k. Saunders Valley and Avin Sink

8. Soils

Soils in the planning area are derived from windblown loess, from alluvials, and from colluvials and residuals originating from the weathering of shale, sandstone, cherty dolomitic limestone and dolomitic bedrock. Soil cover, including unconsolidated deposits, is variable, with little or none on the hilltops, but ranging from about 5 to 25 feet in depth over most of the area (3).

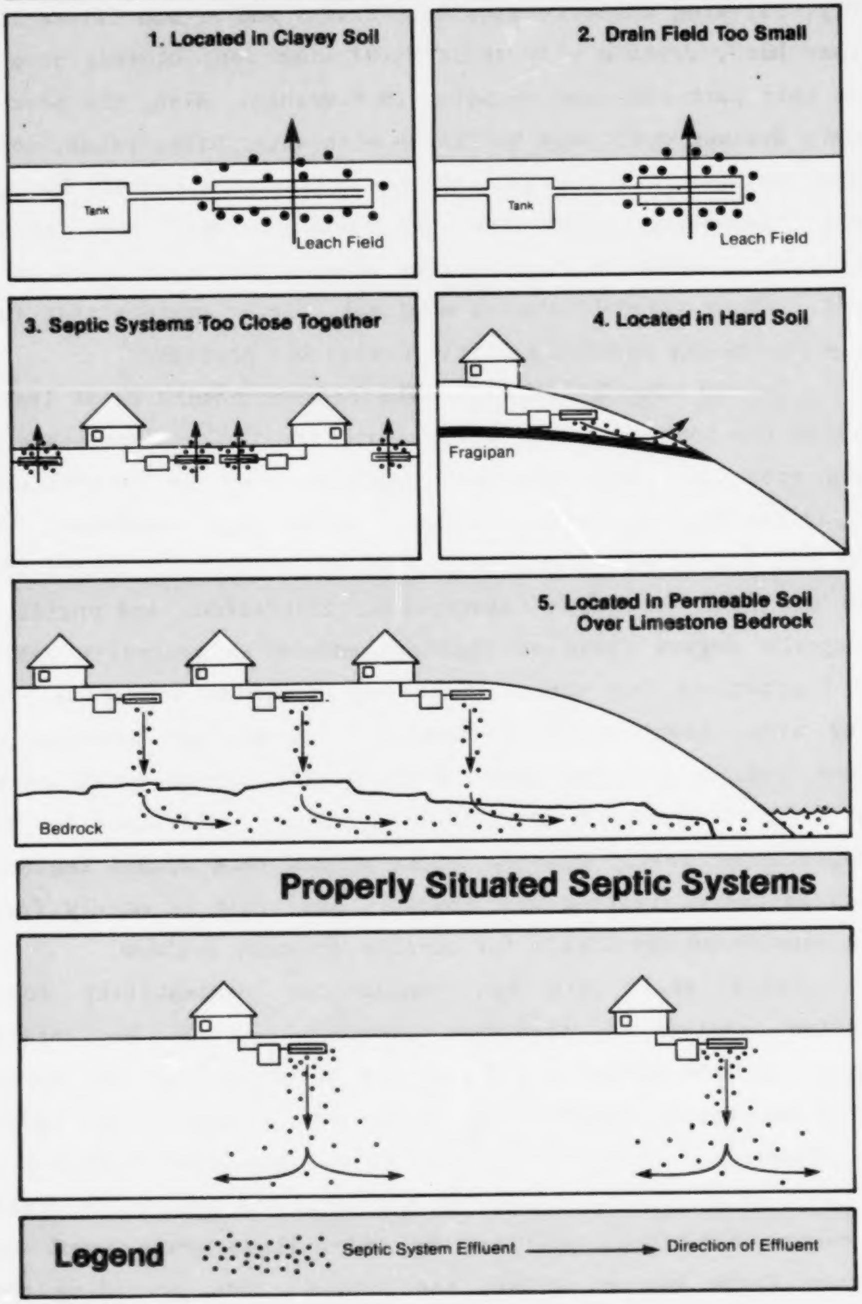
a. Factors Affecting On-site Disposal Systems. Several soil characteristics are important with regard to septic system applications. These characteristics include permeability, ground water level, depth to rock, slope, and proximity to lakes and streams (see Figure 7). Septic system absorption field failure can be caused by poor drainage, seasonal flooding, a high water table, steep slopes, or shallow bedrock.

1) Permeability. Permeability is the capacity of a porous medium, such as soil or rock, to transmit a fluid without changing the structure of the medium; it is a measure of the relative ease of fluid flow under unequal pressure (26).

Septic tank effluent is filtered by the soil in the absorption field. This filtration removes odors, prevents pooling of contaminated effluent on the ground surface, and prevents ground water contamination. Improper filtration leads to water contamination, the potential spread of disease, and offensive odors.

Impermeable soils and those with fragipans (a soil layer with very low porosity) are considered unsuitable for septic systems unless the fragipan is more than four feet below the system laterals. For satisfactory performance, soils should be well drained to transmit effluent (along with rainwater) through the absorption field, but should

Figure 7 **Improperly Situated Septic Systems**


1. Located in Clayey Soil
Tank
Leach Field
2. Drain Field Too Small
Tank
Leach Field
3. Septic Systems Too Close Together
4. Located in Hard Soil
Fragipan
5. Located in Permeable Soil Over Limestone Bedrock
Bedrock
Properly Situated Septic Systems
Legend
Septic System Effluent
Direction of Effluent

Sources: (28,29,30,31)

not be excessively permeable, or filtration will be insufficient. Almost all dry soils absorb water, but non-shrink soils become blocky when dry, allowing water to flow into cracks and escape filtration. On the other hand, certain clay soils swell when wet, closing pore spaces between soil particles and becoming impermeable. Also, the pore spaces in poorly drained soils may be filled with water after rains, sometimes for long periods. These factors are often overlooked during site surveys. Depending upon how percolation tests are conducted, satisfactory percolation rates in dry seasons may be obtained in almost any soil. Where permeability is marginal, septic systems that function properly during dry seasons may fail during wet periods.

2) Depth to Rock. The bedrock should be at least four feet below the bottom of the lateral trenches (33). Experience in the planning area has shown that 4-ft depth to rock is insufficient for proper filtration in soils of stony, silty clay residuum. Shallow bedrock does not allow septic system effluent sufficient travel distance through the soil for proper absorption, filtration, and purification. Soil experts regard areas of shallow bedrock as generally possessing severe limitations for conventional septic system operation. In the planning area, where solution channels, cracks, and crevices in the limestone bedrock provide downward-percolating water quick access to aquifers, it is especially important to observe guidelines for minimum soil depth under septic systems. Some broken rock within the soils is not detrimental to filtration. However, soil that is mainly fractured rock is considered unsuitable for on-site disposal systems.

Where soils are too shallow or permeability too low, alternative wastewater treatment measures should be considered. Enlarging the absorption field is one solution, but is not always practical because of restrictions on lot size or cost of the additional lateral lines. In some areas, soil is so thin that a septic system cannot work satisfactorily no matter how large the absorption field. In these cases, additional soil may be added above grade level and the absorption field located within the "mound", thus providing adequate filtration before the effluent reaches bedrock. Offsite treatment at a more favorable location or surface treatment and disposal systems might also be applicable. Small lagoon systems or mechanical treatment plants may be used to treat wastewater to standards for surface discharge.

3) Ground Water Level. To prevent inundation of the absorption field by ground water, the ground water table should be at least four feet below the absorption field drain tile during the wettest season (32). Saturated soils surrounding a septic system drain field can cause ponding on the ground surface and septic discharge from the system laterals. Seasonal fluctuations in the ground water level may result in seasonal septic system failures, especially during the early spring months when the water table is usually high.

Ground water can become "perched" on a fragipan over the main body of groundwater below. Greene County soils with fragipan layers include the Bado, Gerald, Keeno, Needleye, Nixa, Viraton, and Wilderness series. These soils occur in Strafford, Bois d'Arc, Republic, Palmetto, Turner, Battlefield, Walnut Grove, and northwest Springfield.

4) Slope. The ground slope has a direct bearing on the location of septic systems. Soil cover is thinner on steep slopes and tops of ridges. Slopes exceeding 15% are not very suitable for septic systems (32). However, most housing developments are located where the terrain is relatively flat (34).

5) Proximity to Streams and Sinks. Areas subject to flooding - flood plains and sinkholes - are unsuitable for septic systems because flooding the soil prevents the continuous filtration necessary for operation of the absorption field (32).

b. Characteristics of Planning Area Soils. Most soil factors affecting on-site disposal systems are included in soil surveys conducted by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture. Soils are rated by SCS as having "slight," "moderate," or "severe" limitations for septic tank absorption fields or sewage lagoons. Slight limitations indicate few or no problems associated with the construction and operation of lagoons and septic tank absorption fields. A moderate rating indicates problems which require special care when using the particular soil. These include frost heave, high shrink-swell potential, tendency toward differential settlement, slopes, high water able, high rock content, shallow depth to bedrock, and flooding. Severe limitations suggest that soils have such serious problems that their use is highly questionable.

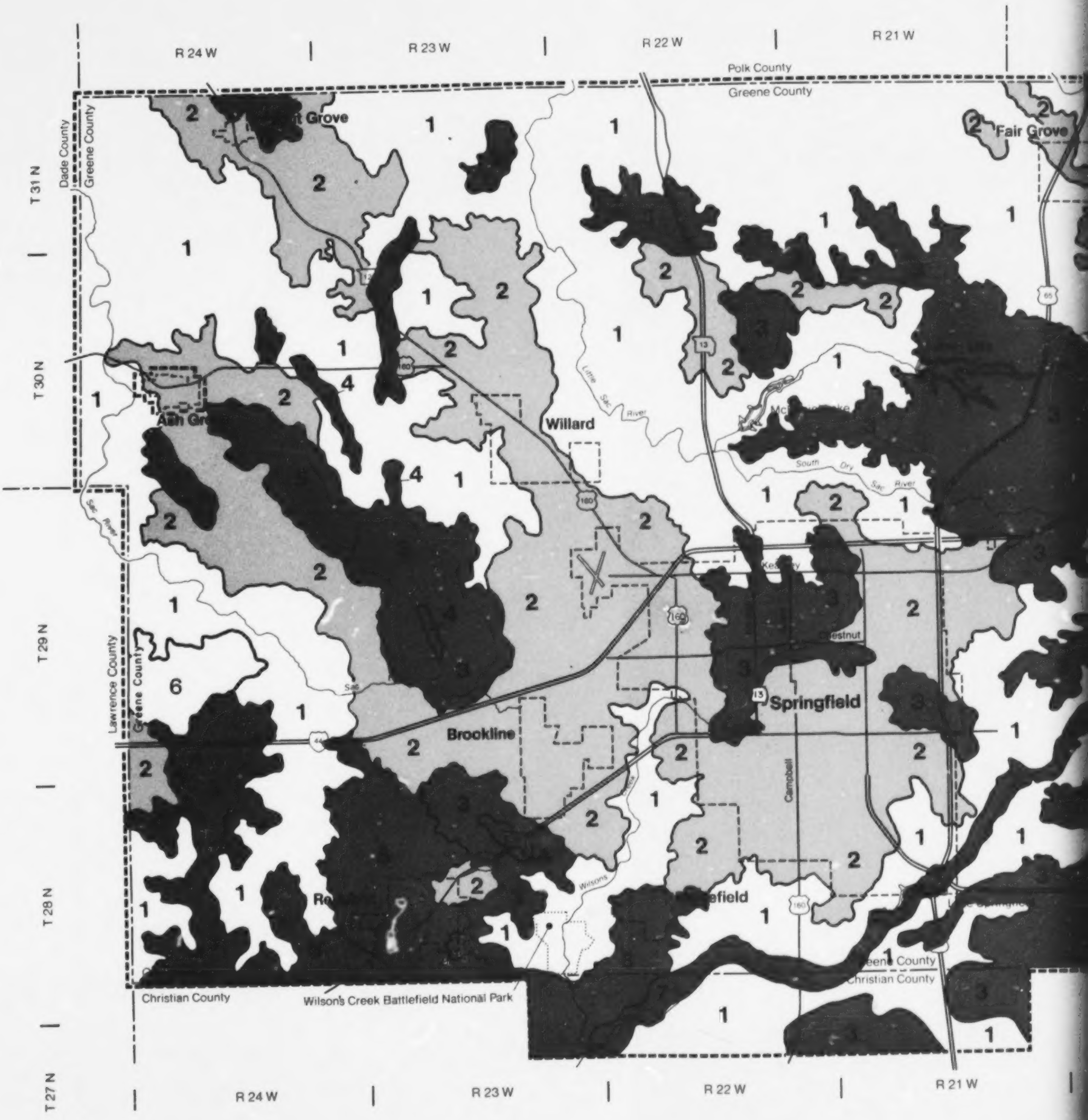
SCS soil maps are prepared from data obtained by field surveys and aerial photography. Soil map accuracy is about 80-90 percent or within about five acres. Soils limitations for sewage treatment facilities are, at best, only an indicator of a broad area. Individual sites may have conditions that are different from the ratings on the maps and tables in this report. Soil limitations do not consider the soil-bedrock unit, landscape setting, and ground water with regard to specific sites.

The limitations of area soils for sewage treatment facilities are listed in Appendix A-Section 3, Table A-1 (25). Descriptions of the soils series and subarea maps showing absorption field suitability and prime farmland are also provided in Appendix A-Section 3. General soil limitations for septic system operation are mapped in Figure 8. For simplicity of illustration, the map shows soil associations comprising several soil series. Within these broad areas, individual sites may differ from the area as a whole in suitability for septic systems. Each building site with a proposed septic system should thus be examined for suitability. The Greene County Building, Planning, and Zoning Department should be consulted in this regard.

B. WATER RESOURCES

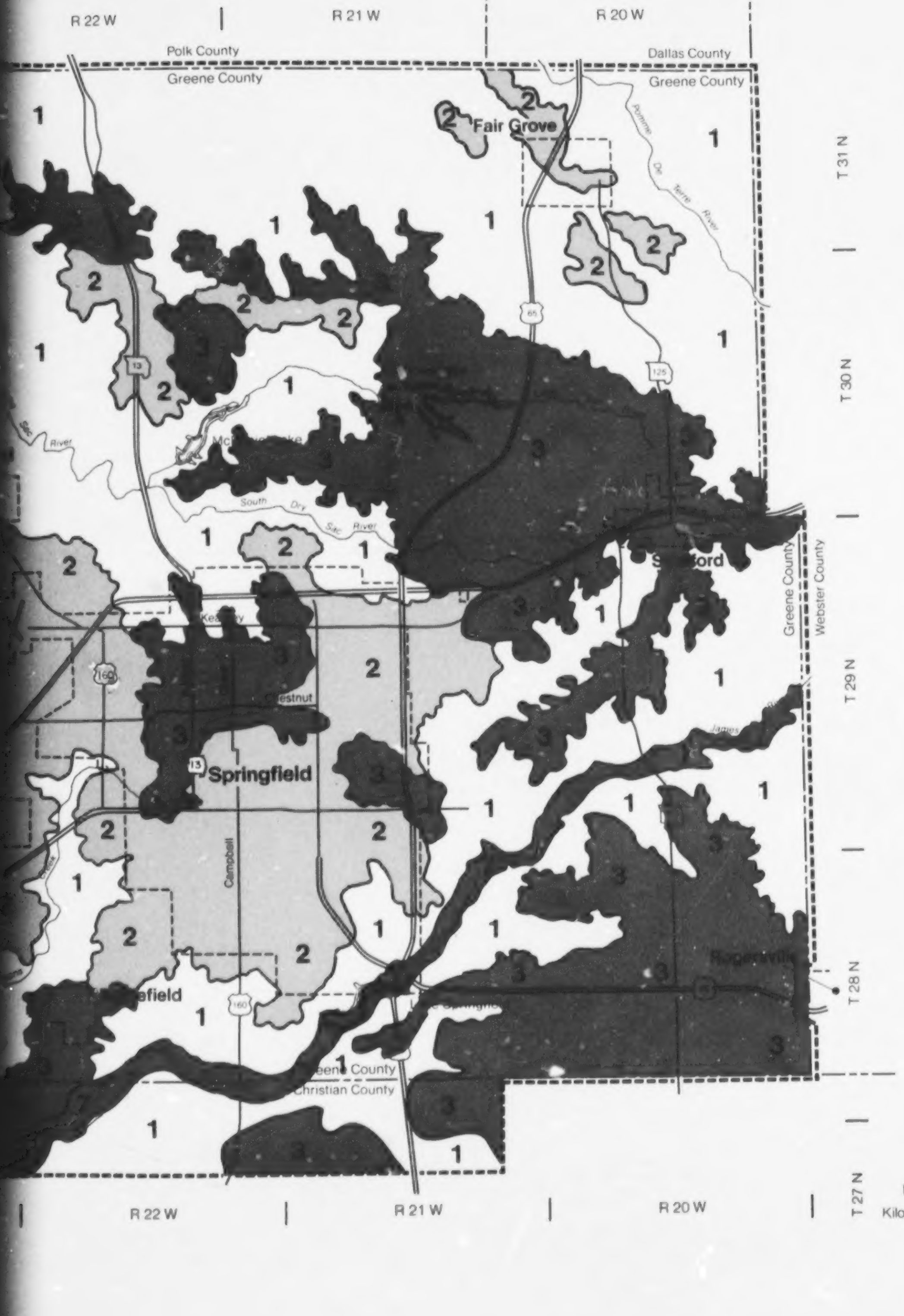
1. Surface Water

a. Drainage Basins. The planning area is divided between two drainage basins - the Osage to the north and the White to the south. The line that divides the two basins crosses Greene County from Republic to Strafford, roughly following the route of the St. Louis and San Francisco Railway. The area's location on a drainage divide has important water resources and water quality implications. Since streams originate near the divides, those in the planning area are small, limiting water supply resources and flows to assimilate pollutants.


R 24 W
R 23 W
R 22 W
R 21 W
Polk County
Greene County
Dade County
Greene County
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
Fair Grove
Willard
Ash Gro
t Grove
Little Sac River
South Dry Sac River
Sac River
Mc
Kearney
Chestnut
Springfield
Campbell
Brookline
Lawrence County
Greene County
Re
efield
Wilsons
Greene County
Christian County
Christian County
Wilson's Creek Battlefield National Park
1
2
3
4
6
7

Generalized Soil Limitations for Septic System Operation

Figure 8



Legend

Soils Association

1 Goss – Wilderness – Peridge
2 Pembroke – Eldon – Creldon
3 Wilderness – Viration
4 Basehor – Boliva
5 Keeno – Creldon
6 Clarksville – Nixa
7 Huntington

Rating for Septic System Suitability

☐	Slight
▨	Moderate
■	Severe

Sources: (24,25)

Planning Area - - - - -
City Limits - - - - - -
County Limits - - —— -

Miles 1 2 3 4
Kilometer 1 2 3 4 5 6
North

Table 1 and Figure 9 display the major drainage basins and river systems in Greene County; Figure 9 also shows U.S.G.S. stream monitoring stations.

1) White River Basin. The major streams of the White River Basin in Greene County are the James River and Wilsons Creek.* The White River basin covers the southern part of Greene County, including 80% of the City of Springfield (33). Runoff from Springfield is carried principally by Wilsons Creek, which enters the James River in Christian County near the southern boundary of the Planning Area. The eastern area of the basin in Greene County drains into tributaries of the James River. The largest of these tributaries are Pierson, Sawyer, and Turner Creeks. The drainage area of the James River just above its confluence with Wilsons Creek is 320 square miles. The James, a tributary of the White River, originates in Webster County about 30 miles east of Springfield and flows in a southwesterly direction (36). It passes through the extreme southeast corner of Springfield and is impounded within the city limits to form Lake Springfield, which provides cooling water for the James River Power Plant (36, 43). The lake was created in 1957 by the construction of an earth- and rock-fill dam, and is approximately one-half square mile in area (37).

Annual low flows in the White River basin streams in Greene County usually occur in late summer (36). Flow data for selected streams are given in Table 2. The average flow of the James River below Pierson Creek but above its confluence with Wilsons Creek is 212 cubic feet per second (cfs); however, the 7-day, 10-year low flow (7Q10), the lowest 7-day flow expected during any given 10-year period, is only 1.0 cfs (10, 38, 39). The flow in Wilsons Creek near Springfield (one mile upstream of Springfield's Southwest Treatment Plant) averages 28.2 cfs, but declines to zero at times during most years (38). Flows in the upstream tributaries of Wilsons Creek frequently consist entirely of municipal and industrial wastewaters during drought periods (36, 40).

---

*As the creek name, the correct spelling is "Wilsons"; as the name of the battlefield park, it is "Wilson's."

TABLE 1
RIVER SYSTEMS

Mainstem and Tributaries(a)	Drainage Area (in the Planning Area) (sq. mi.)	Mainstem and Tributaries(a)	Drainage Area (in the Planning Area) (sq. mi.)
WHITE RIVER BASIN		OSAGE RIVER BASIN	
Wilsons Creek (b)	71	Sycamore Creek	16
Jordan Creek		Billies Creek	
Fassnight Creek		Turnback Creek	
Nichols Branch			
South Creek		Sac River (b)	96
McElhaney Branch (b)		Pond Creek (b)	
Shuyler Creek (b)		Dry Branch	
Terrell Creek (b)		Pickerel Creek (b)	
		Mathew Brown Branch	
James River	164	Hall Branch	
Millan Hollow		Dry Branch	
Canyon Hollow		Hawkins Branch	
Davis Creek (b)			
Broad Creek (b)		Clear Creek	80
Sawyer Creek		Rainer Branch	
Turner Creek		Big Hollow	
Big Hollow		Mt. Pleasant Branch (b)	
Jones Branch		Sawdey Branch	
Pierson Creek (b)		Staley Branch	
Galloway Creek		Sugar Creek (b)	
Hunt Branch		Kelly Branch	
Farmer Branch			
Workman Branch		Asher Creek (b)	28
Ward Branch			

TABLE 1 (continued)
RIVER SYSTEMS

Mainstem and Tributaries(a)	Drainage Area (in the Planning Area) (sq. mi.)	Mainstem and Tributaries(a)	Drainage Area (in the Planning Area) (sq. mi.)
WHITE RIVER BASIN		OSAGE RIVER BASIN	
		Little Sac River	109
		South Dry Sac River (b)	
		Pea Ridge Creek	
		Spring Branch	
		Flint Hill Branch	
		Turkey Creek (b)	
		North Dry Sac River	37
		Sims Branch	
		King Branch	
		Oak Grove Branch	
		Little Pomme de Terre River	23
		Spring Creek	
		Pomme de Terre River	28
		South Fork (b)	
		Polk Spring Branch	
		Selph Branch	
		Mutton Hollow	

(a) Listed in order from upstream to downstream.

(b) Includes segments that are losing.

TABLE 2
WHITE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
James River near Strafford 1 mi. (1.6 km) below Davis Ck.(a)	average: 148 minimum: 1.2 (June 1977)	1974-81
James River near Springfield, 1.1 mi (1.8 km) below Pierson Ck.	average: 212(a) 7Q10*: 1.0(c) 7Q 2**: 11.0(c) minimum: 0.1(a) (Sept. 1956)	1956-81 1956-72 1956-72 1956-81
James River below Battlefield, in Christian County(b)	7Q10: 5.4 7Q2: 16.0	1929-32
Wilson Creek near Springfield, 1 mi. upstream of Springfield's Southwest Wastewater Treatment Plant(a)	average: 28.2 minimum: 0	1973-81
Wilsons Creek near Battlefield, 0.3 mi upstream from McElhaney Branch(a)	average: 91.1 minimum: 7.6 (Aug. 1970)	1968-70 and 1973-81
Indian Branch near Battlefield (d)	0	2-21-83
Pierson Creek(c): (listed from upstream down)		
4 mi. east of Springfield at county highway ford	0.5	9-10-73
4 mi. east of Springfield at county highway ford	3.6	8-20-74

TABLE 2 (continued)

WHITE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
3 mi. east of Springfield, at County Highway YY bridge	4.0	8-20-74
	11.1	2-20-75
1.5 mi. east of Springfield, at county highway ford	2.5	9-10-73
	4.8	8-20-74
	12.3	2-20-75
1 mi. east of Springfield, at Cherry St. Road Bridge	0.4	9-10-73
	12.0	2-20-75
1 mi. east of Springfield adjacent to Cherry Valley Estates	0	9-10-73
	0.	8-20-74
	3.2	2-20-75
1 mi. east of Springfield, at county highway bridge	1.0	9-10-73
	1.5	8-20-74
	15.0	2-20-75
1 mi. east of Springfield, at railroad bridge, 0.75 mi. upstream from James River	21.0	2-20-75
2 mi. east of Springfield, at mouth	4.0	9-10-73
	9.6	8-20-74
Davis Creek, 3 mi. southeast of Strafford, about 0.5 mi above James River(c)	0	9-11-73

TABLE 2 (continued)
WHITE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
Davis Creek[d]: (listed upstream down)		
1.5 mi. southeast of Strafford	1-2	2-22-83
2 mi. southeast of Strafford	0	2-22-83
3 mi. southeast of Strafford	Not 0	2-22-83
Broad Creek, 4 mi. south of Strafford, about 0.5 mi above James River[c]	0	9-11-73

* 7Q10 is the lowest 7-day flow expected in any 10-year period.

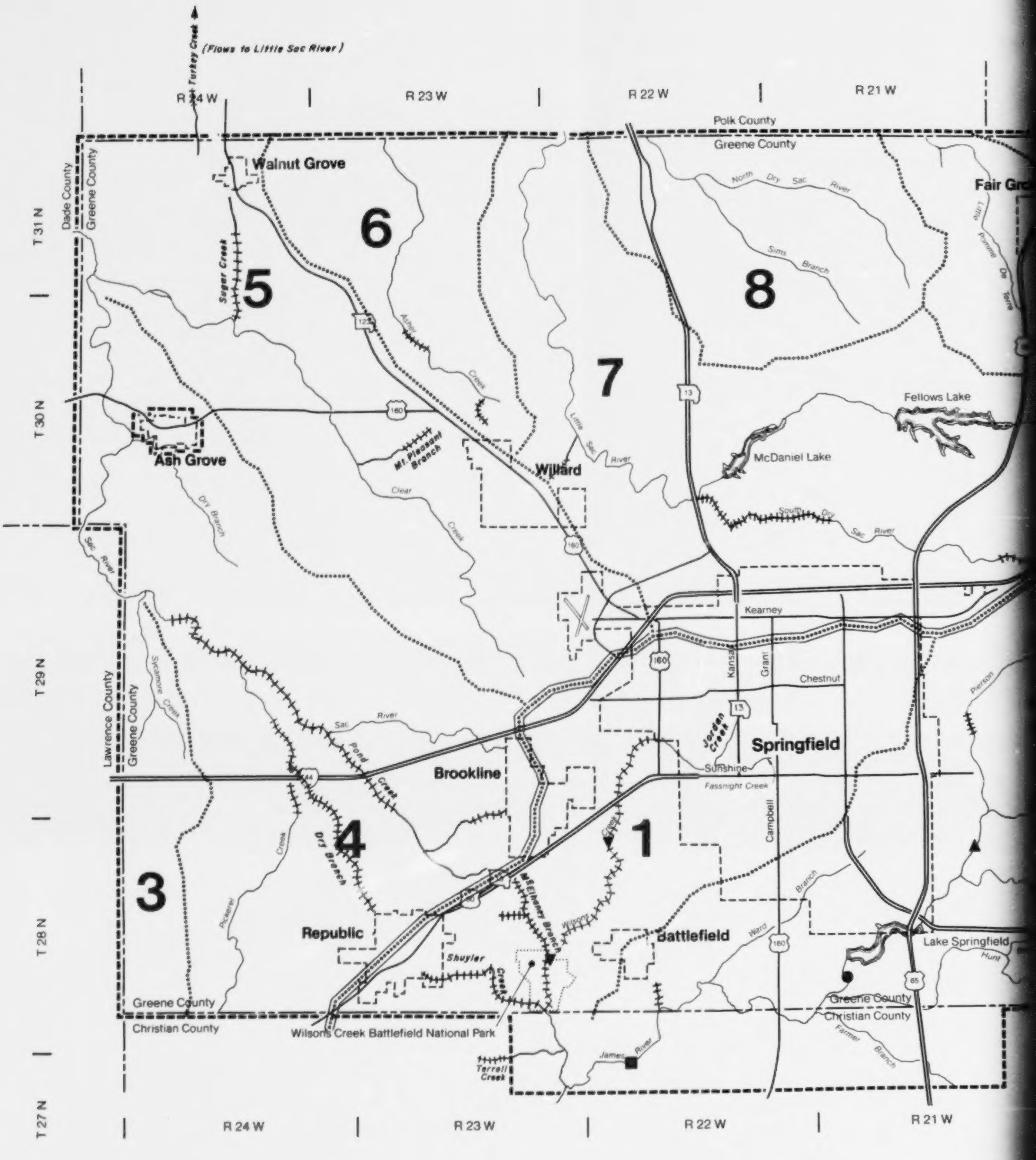
** 7Q2 is the lowest 7-day flow expected in any 2-year period.

Sources: (a)(38)

(b)(10)

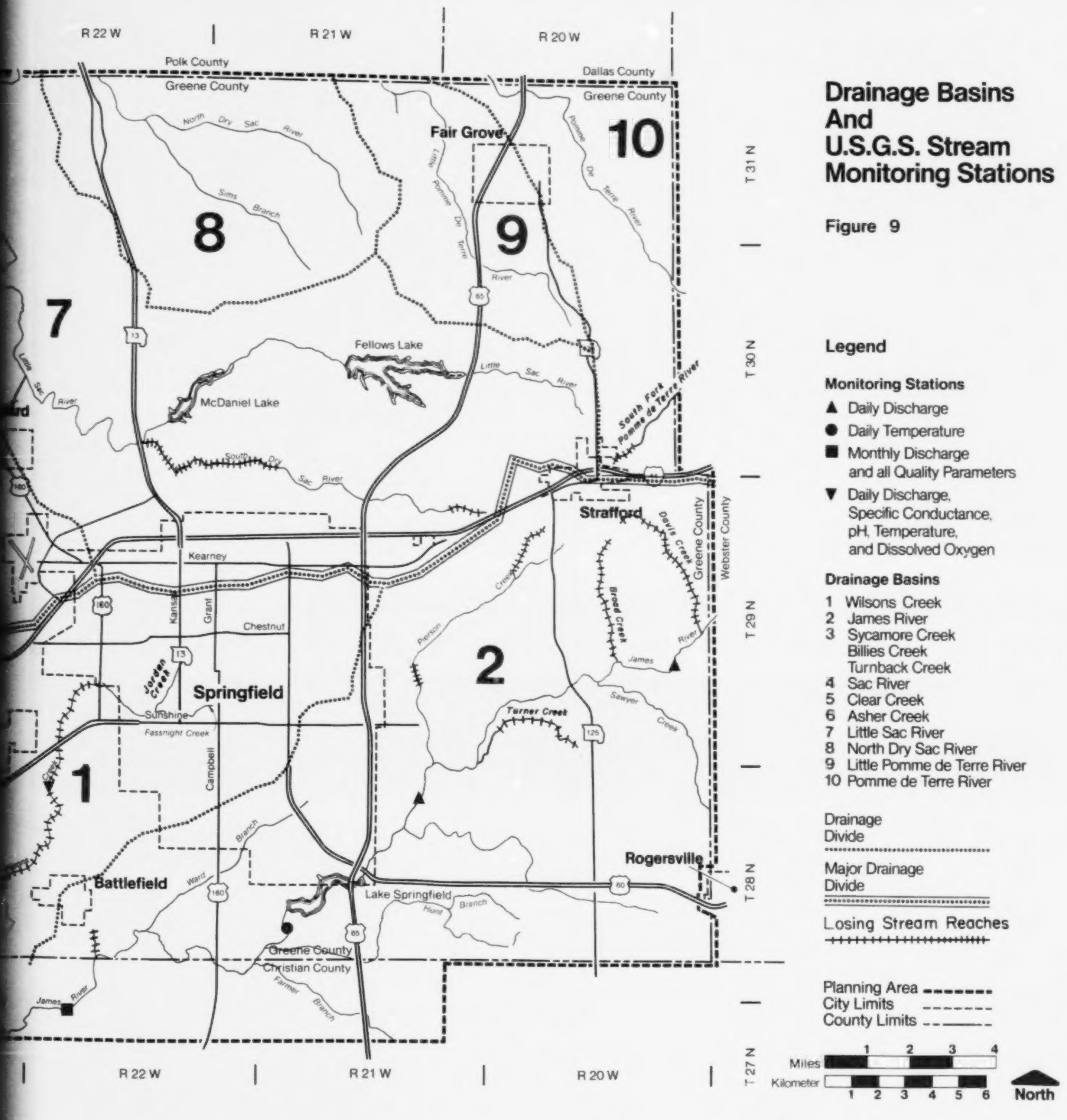
(c)(13)

(d)Field estimate of EIS consultant.


Turkey Creek
(Flows to Little Sac River)
R 24 W
R 23 W
R 22 W
R 21 W
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
Polk County
Greene County
Dade County
Greene County
Lawrence County
Greene County
Greene County
Christian County
Greene County
Christian County
Walnut Grove
Fair Gro
Ash Grove
Willard
Brookline
Republic
Battlefield
Springfield
1
3
4
5
6
7
8
Sugar Creek
Asher Creek
Mt. Pleasant Branch
Clear Creek
Little Sac River
North Dry Sac River
Sims Branch
Little Pomme De Terre
Fellows Lake
McDaniel Lake
South Dry Sac River
Dry Branch
Sac River
Sycamore Creek
Sac River
Pond Creek
Dry Branch
Pickerel Creek
Jordan Creek
Fassnight Creek
Creek
McElhaney Branch
Wilsons Creek
Shuyler Creek
Ward Branch
Pierson
Lake Springfield
Hunt
Farmer Branch
James River
Terrell Creek
Wilsons Creek Battlefield National Park
Kearney
Chestnut
Sunshine
Kansas
Grant
Campbell
123
160
13
160
13
44
160
65

Drainage Basins And U.S.G.S. Stream Monitoring Stations

Figure 9



2) Osage River Basin. Streams in the northern and western areas of Greene County discharge into the Sac River or the Pomme de Terre River, both tributaries of the Osage River. The major tributaries of the Sac River in Greene County are Pickerel Creek, Clear Creek, Asher Creek, the Little Sac River, the South Dry Sac River, and the North Dry Sac River. Sac River tributaries draining the southwest corner of Greene County are Sycamore, Billies, and Turnback creeks. Pickerel Creek originates in Christian County south of the planning area, flows north, and discharges into the Sac River near the Lawrence County-Greene County border. Clear Creek originates at the northwestern city limits of Springfield, flows northwesterly, and empties into the Sac River at the Dade County-Greene County border. Asher Creek originates near the City of Willard, flows north, and discharges into the Little Sac River about one and three-fourths miles north of Greene County.

The Little Sac River originates northeast of Springfield and flows westward into Fellows Lake and then into McDaniel Lake. These impoundments were built for drinking water supply use of the City of Springfield. Their drainage areas are about 22 square miles and 20 square miles, respectively. Their storage capacities are about 9 billion and 1 billion gallons, respectively (41, 42). The North Dry Sac River originates in north central Greene County, flows northwesterly, and joins the Little Sac River one and one-quarter miles north of Greene County. The South Dry Sac River originates near the northeastern tip of Springfield, flows west, and empties into the Little Sac just east of Highway 13. The Little Sac joins the Sac River at Stockton Reservoir, northwest of Greene County.

The Little Pomme de Terre and the Pomme de Terre rivers drain the northeast corner of Greene County. They flow northwest, and converge about two miles north of Greene County.

The Osage streams in Greene County are supplemented by springs and by effluents from industries and municipalities; these sources are especially important during low flows. Several of the streams become completely dry during drought periods, generally in mid-summer (36).

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Flow data for selected streams are given in Table 3. Flows in the Sac River near Dadeville about 4 miles northwest of Greene County have averaged 210 cfs for the past 15 years (54). The "total drought flow" of the Little Sac River 7.3 stream miles downstream of Springfield's Northwest Wastewater Treatment Plant, exclusive of plant effluent, is approximately 1.5 cfs (36).

b. Runoff. Mean annual runoff in the planning area is estimated at 12 inches, or about 30 percent of the mean annual precipitation of 41 inches (12, 44). Evapo-transpiration accounts for most of the remaining 70 percent. Development increases surface runoff volume over natural conditions at the following estimated rates (12).

	Percent Increase in Runoff	
Development	Range	Mean
Suburban	48 to 69	59
City Housing	70 to 90	80
Apartments/Business	90 to 127	108
Industrial/Commercial	127 to 153	140

Runoff from the downtown Springfield area is rapid due to steep gradients and a high proportion of paved and roofed areas (40). Runoff is also rapid over natural impervious areas, steep slopes, and areas where vegetation has been removed.

c. Flood-prone Areas. Most of the major streams in the planning area, even those with subsurface drainage, flood periodically. The flat land that can be inundated is referred to as a "floodplain." Most of the sinkholes also flood. Flooding also occurs where the storm sewer system is inadequate.

1) Floodplains. The James River floodplain is relatively undeveloped, but major subdivisions are located at the edge of the floodplain and the city is expanding toward the river. The Pierson Creek floodplain is still unaffected by urban development but growth from suburban Springfield is occurring in western portions of the watershed. Galloway Creek and Ward Branch originate in Springfield and their floodplains contain a considerable amount of urban development.

TABLE 3

OSAGE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
Sac River at Ash Grove[(b)]	7Q2: 13 7Q10: 3.5	1962-65, 1967, and 1971
Sac River near Dadeville, in Dade County	average: 212(a) 7Q2: 18(b) minimum: 4.0(a) (June 1980)	1966-1981 1966-72 1966-1981
Little Sac River near Morrisville in Polk County(b)	7Q2: 6	1968-72
Little Sac River(c): (listed from upstream down)		
3 mi. northwest of Strafford	0.4	11-16-71
4.5 mi. north of Springfield, at Highway 13 bridge	2.9	11-16-71
2 mi. north of Springfield, at Highway 13 bridge	0	11-16-71
2 mi. east of Willard	7.9	11-16-71
1 mi. east of Sacville	13.0	11-16-71
Asher Creek: (listed from upstream down)		
Near Willard(d)	0	2-22-83
4 mi. northeast of Walnut Grove(c)	2.5	11-17-71

TABLE 3 (continued)
OSAGE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
Clear Creek, 2.5 mi. west of Phenix	7Q2: 5.0 7Q10: 1.0	1962-64, 1967, and 1970-71
Clear Creek: (listed upstream to down)		
2 mi. southwest of Willard(c)	2.2	1-16-71
Southwest of Willard(d)	10-12	2-22-83
5 mi. southeast of Ash Grove(c)	8.7	8-22-74
3.5 mi. west of Willard(c)	5.0	11-16-71
1 mi. south of Phenix(c)	7.5	11-17-71
Pond Creek near Brookline(d)	6-8	2-21-83
Pickerel Creek near Republic(b)	7Q2: 0.0	1968-70
Dry Branch(d)		
Near Republic Treatment Plant	2-4	2-21-83
3 mi. downstream of treatment plant	0	2-21-83
Pomme de Terre River near Bolivar in Polk County(b)	7Q2: 2.6 7Q10: 0.4	1951-69

TABLE 3 (continued)
OSAGE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
South Fork Pomme de Terre River:		
4 mi. northeast of Strafford(c)	3.5	8-23-74
Northwest of Strafford(d)	5-6	2-23-83
Pomme De Terre River: (listed from upstream down)		
4.5 mi. southeast of Fair Grove, about 0.5 mi. below confluence of North and South forks.(c)	3.5 6.0	11-15-71 8-23-74
1.5 mi. east of Fair Grove(c)	4.8	11-15-71
East of Fair Grove(d)	30-40	2-23-83
2.5 mi. northeast of Fair Grove(c)	5.7	11-15-71
Little Pomme de Terre River: (listed from upstream down)		
2 mi. southeast of Fair Grove(c)	0.05	11-15-71
2 mi. southwest of Fair Grove(c)	0.3	8-23-74
1 mi. southwest of Fair Grove(c)	1.0	11-15-71
1 mi. west of Fair Grove(c)	2.0	11-15-71

TABLE 3 (continued)
OSAGE RIVER BASIN STREAM FLOWS

Stream and Location	Flow (cfs)	Period
West of Fair Grove[d]	10-12	2-23-83
2 mi. northwest of Fair Grove[c]	2.5	11-15-71
Sugar Creek near Walnut Grove[d]	1-2	2-22-83
Turkey Creek near Walnut Grove[d]	0	2-22-83
Turkey Creek tributary near Walnut Grove[d]	3-4	2-22-83

Sources:

(a)(38)

(b)(10)

(c)(13)

(d)Field estimate of EIS consultant.

There are important areas of development within the Wilsons Creek drainage basin that are subject to inundation by larger floods. The floodplains of Jordan, Fassnight and South creeks are heavily developed with both commercial and residential growth. Only a few homes in these floodplains have been severely damaged by floods; however, a large number have had basement flooding. Greene County has adopted zoning regulations creating a Floodplain District. The regulations are designed to limit development in the floodplain to minimize flood damage (47).

Flood areas (see Figure 10), based upon the estimated 100-year flood, have been determined for Springfield and the rest of Greene County. Flood insurance studies prepared for the Federal Insurance Administration (FIA) by the Corps of Engineers, Little Rock District, cover areas within the City of Springfield. The flood boundaries, including sinkhole areas, for the City were delineated by Dames and Moore for FIA in 1977. A study for the Federal Emergency Management Agency (FEMA), successor to FIA, was prepared for the rest of Greene County by the Corps of Engineers. Detailed study methods were used in areas of known flood hazard and projected development, and more approximate methods used in areas of low hazard and development potential.

The "floodway," as outlined in the studies, includes the stream channel and any adjacent floodplain areas that should be kept free of encroachment, such that the channel can carry the 100-year flood without increasing the flood crest. Floodway data are presented in Appendix B - Table B-1.

2) Sinkholes. About 20 to 30 percent of Greene County drains into sinks (see Figure 10). Sinkholes may flood in several ways and flooding may persist for days or even weeks. A sinkhole that has been plugged, either artifically or naturally, will flood during periods of heavy rainfall, and may take a long time to dry out through slow drainage and evaporation. A swallow hole or open type of sinkhole may flood temporarily when flow exceeds the capacity of the opening or the underground lateral transport conduits. In the latter situation, there

may be upward flow through a sinkhole. Filling a sinkhole may disrupt natural drainage and increase flooding in adjacent areas. Indiscriminate filling of sinkholes in the City of Springfield was allowed until 1975 when an ordinance was passed recognizing sinkholes to be natural drainage ways and prohibited the filling, partial filling, or draining of such drainageways (3). The City of Springfield has also established minimum floor elevations for structures constructed in sinkholes. No permanent structures are allowed below the minimum floor elevation. In certain cases, runoff detention is required to avoid overloading sinkhole and swallow hole capacity (3, 52).

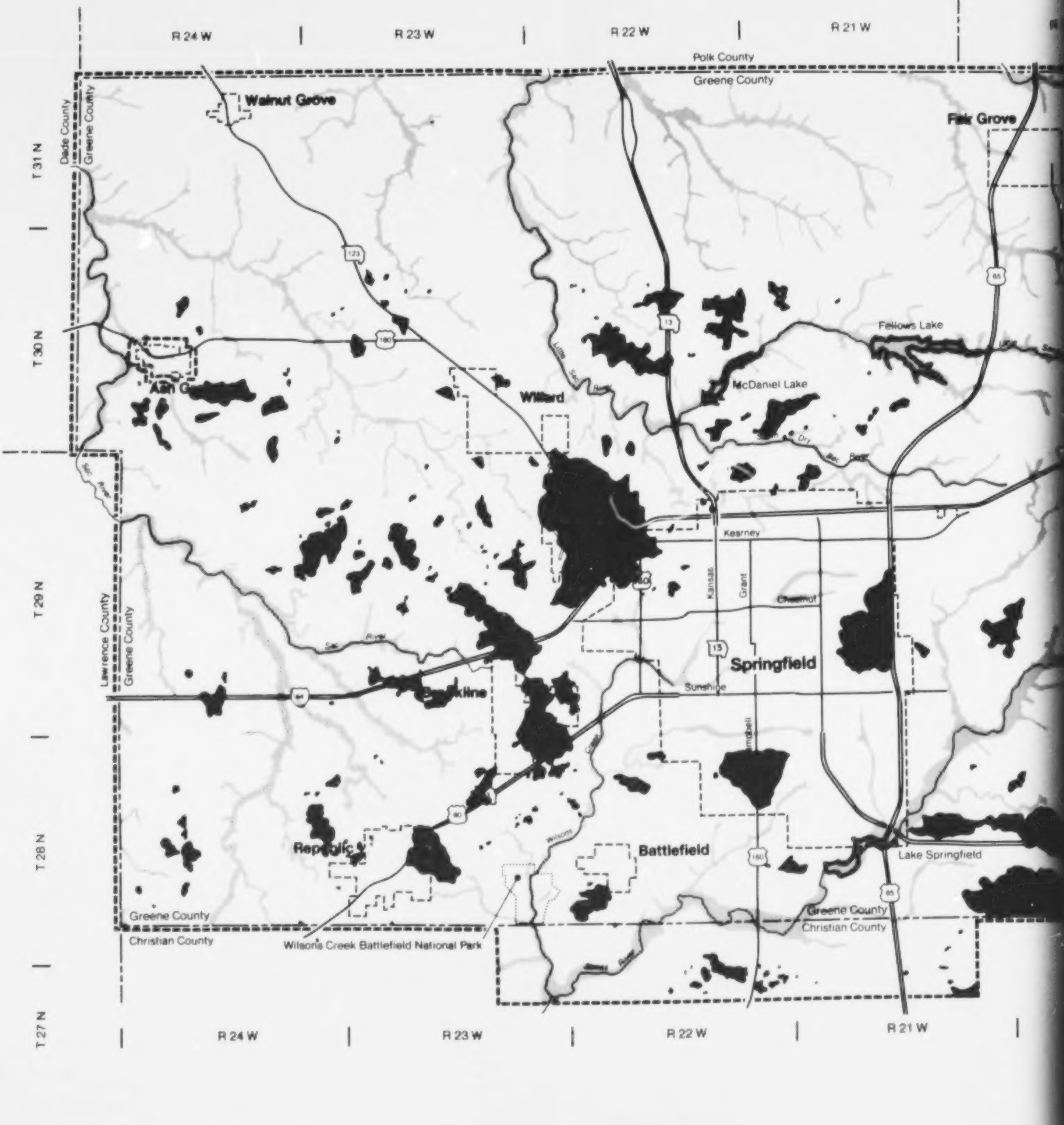
2. Ground Water.

a. Aquifers. Ground water is considered to be the water in the zone of saturation where all pores are filled with water. An aquifer is a saturated formation that will yield water to wells or springs at a sufficient rate to serve as a practical source of water supply.

The planning area has two aquifers; a major (deep) aquifer and a minor (shallow) aquifer. The two aquifers are separated by the Northview Formation at or near the base of the minor aquifer. This formation, consisting of shale and shelfstone, retards the downward movement of water and acts as the upper confining layer to the major aquifer.

The major aquifer is over 1,000 feet thick and consists primarily of dolomite with minor sandstone units. It includes the strategraphic sequence from the Potosi Dolomite up to the Cotter Dolomite. The minor aquifer consists mainly of cherty limestone above the Northview Formation (see Figure 4). Rocks of the minor aquifer are at or near the surface over most of the planning area and are deeply weathered with openings such as sinkholes and caves. These openings allow rather rapid movements of water into and through the aquifer.

The minor aquifer in the alluvials, the Burlington Limestone, and other formations above the Northview Shale yields up to 20 gallons/minute. The major aquifer in the formations below the Northview contains a large amount of water most of which is under artesian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Polk County
Greene County
Walnut Grove
Fair Grove
Dade County
Greene County
T 31 N
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T 28 N
T 27 N
123
160
13
65
Fellows Lake
McDaniel Lake
Willard
Ash G
Little Sac River
Sac River
Dry Sac River
Kearney
Kansas
Grant
Chestnut
Springfield
Sunshine
Campbell
Lawrence County
Greene County
44
Brookline
Republic
60
Battlefield
Wilsons Creek
Lake Springfield
Greene County
Christian County
Wilsons Creek Battlefield National Park
James River
R 24 W
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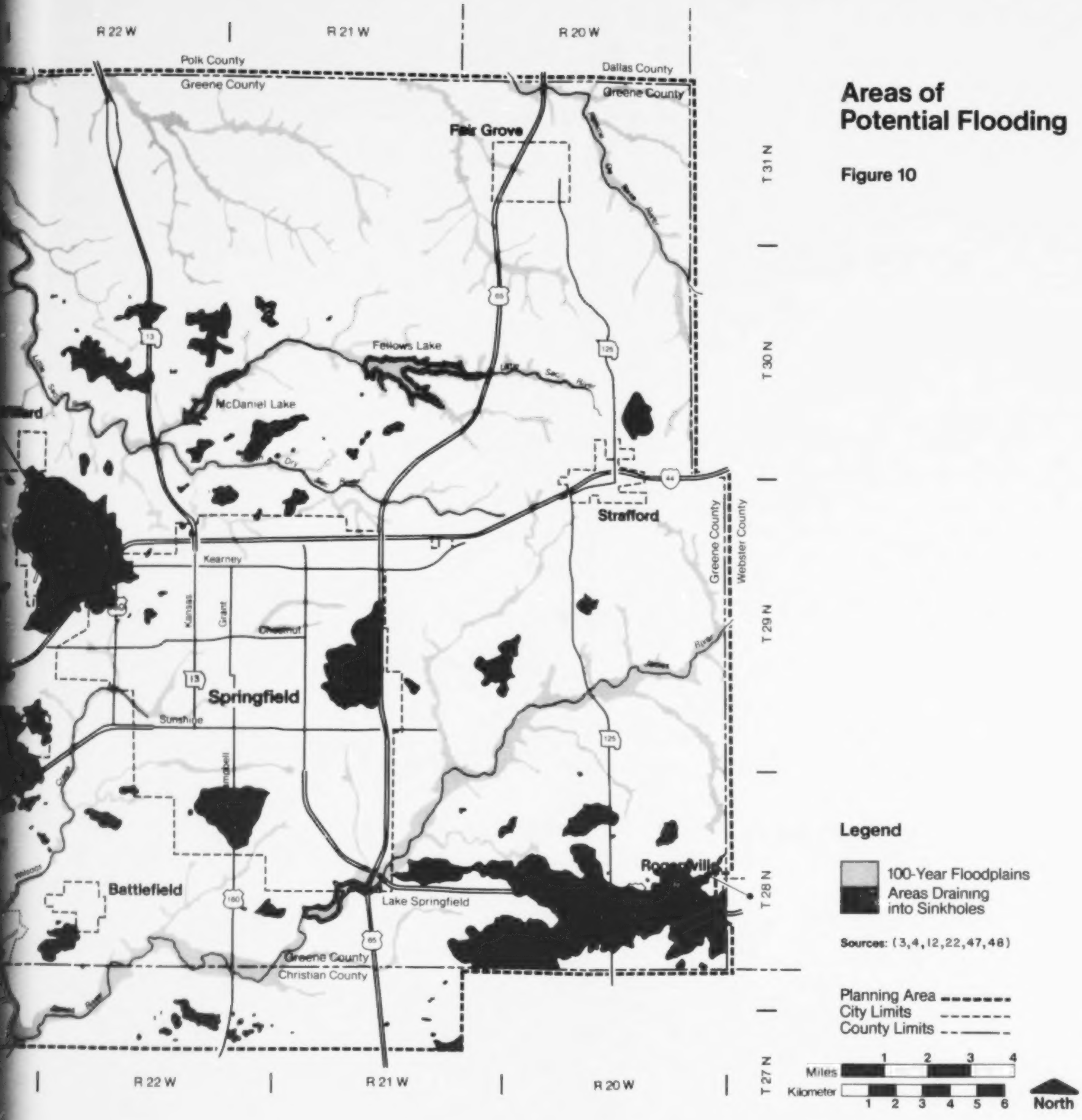
R 22 W
R 21 W

Areas of Potential Flooding

Figure 10



Sources: (3,4,12,22,47,48)

pressure. Yields up to 2000 gallons/minute are possible. Most residential and farm wells are drilled into the minor aquifer at depths to about 300 feet. The Springfield city wells and industrial deep wells are in the lower aquifer at depths to about 1700 feet. Springfield also uses Fulbright Spring and Valley Water Mills, a spring-fed reservoir whose principal source is regarded as Sander Spring. Other springs discharge into tributaries of the City's surface water reservoir and stream sources.

b. Ground Water Movement. In the planning area, the ground water in the lower aquifer generally moves northwest following the structural dip of the bedrock away from the Ozark uplift. A ground water divide, however, is located at approximately the Greene-Christian county line, and ground water to the south of this divide moves in a southerly direction, generally following the dip of the bedrock. The elevation of the potentiometric surface (the elevation to which water will rise in a tightly-cased well) at the ground water divide is about 1,200+ feet above sea level. Pumping of Springfield wells causes movement of ground water to the center of a cone of depression in the potentiometric surface surrounding the wells. The regional potentiometric surface of the lower aquifer was measured in June 1974 as about 850 feet above sea level near the junction of the Kansas and Chestnut Expressways (13, 42) (See Figure 11). Outside of this cone, ground water movement is to the northwest on the north side of Springfield and to the south near the Greene-Christian County line.

Understanding ground water movement in the minor aquifer is important, because the large number of surface-subsurface connections facilitate movement of surface water pollutants into the groundwater. Dye traces have been conducted by the Missouri Geological Survey and others to determine ground water flow patterns (see Figure 12). Dyes have been traced from introduction points in sinkholes, streams, and sewer lines to caves, springs, and streams. This approach has yielded limited information mainly because of the multitude of underground connections in the area and because the studies have only been undertaken in response to isolated complaints of pollution. Until there

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is comprehensive testing of streams, sinkholes, sewer lines, etc., throughout the planning area, it will be necessary to extrapolate or postulate flow lines in areas lacking positive testing.

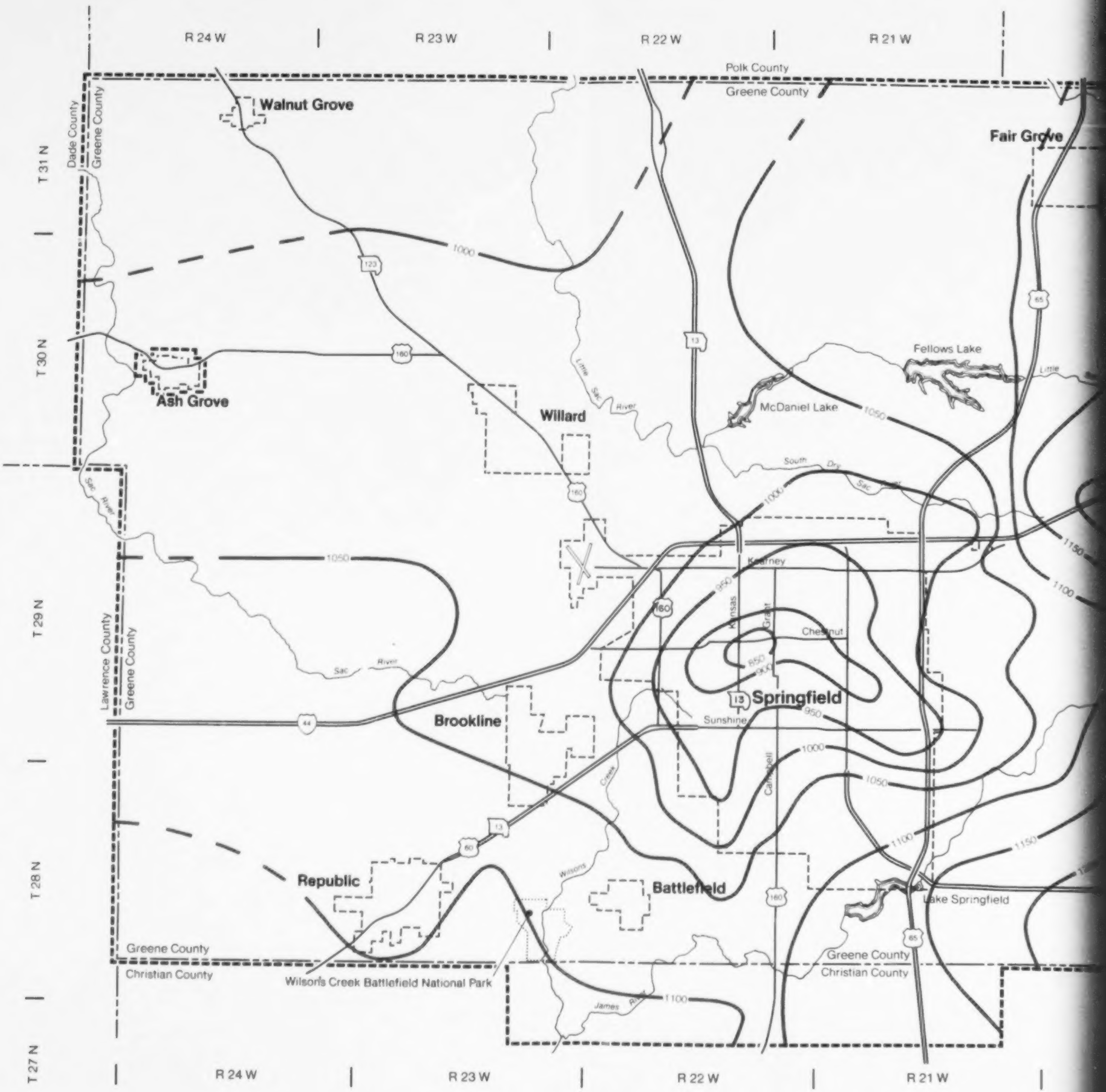
Normally, ground water movement is, of course, downward in response to gravity. Water levels in the minor aquifer are generally higher than those in the major aquifer; therefore, potential movement is downward. However, the Northview Formation retards downward water movement and acts as an upper confining layer to the major aquifer. Water movement to the major aquifer can occur where the Northview is breached either by natural means such as joints and faults or by artificial means such as uncased or improperly cased wells.

c. Recharge Areas. Aquifers are recharged by precipitation. The minor aquifer, at or near the surface, is recharged by rainfall entering open joints and sinkholes and through losing reaches of area streams. Outcropping (or surface exposure) of the major aquifer is limited in the study area, so most local recharge occurs by passage through the minor aquifer and the Northview Formation before entering the major aquifer. Outside of the study area, formations comprising the major aquifer form the bedrock surface and there is direct recharge.

Recharge areas are classified as diffuse, where there is slow percolating movement around each soil particle, or discrete, where there are open water passages with concentrated larger quantities of water flow. Recharge from areas drained by sinkholes is about 75 percent discrete and 25 percent diffuse. Areas of diffuse recharge have a tendency to plug, increasing the amounts of discrete recharge. Areas of discrete recharge, e.g., areas of lineaments, faults, and sinkholes, are considered unsuitable for septic systems. Leachate may be able to bypass soil filtration and flow directly into the ground water system via discrete recharge features, thus contaminating the aquifer (100). Subsurface geology influences recharge and may result in "severe" septic system limitations even though the soil cover has an acceptable rating.

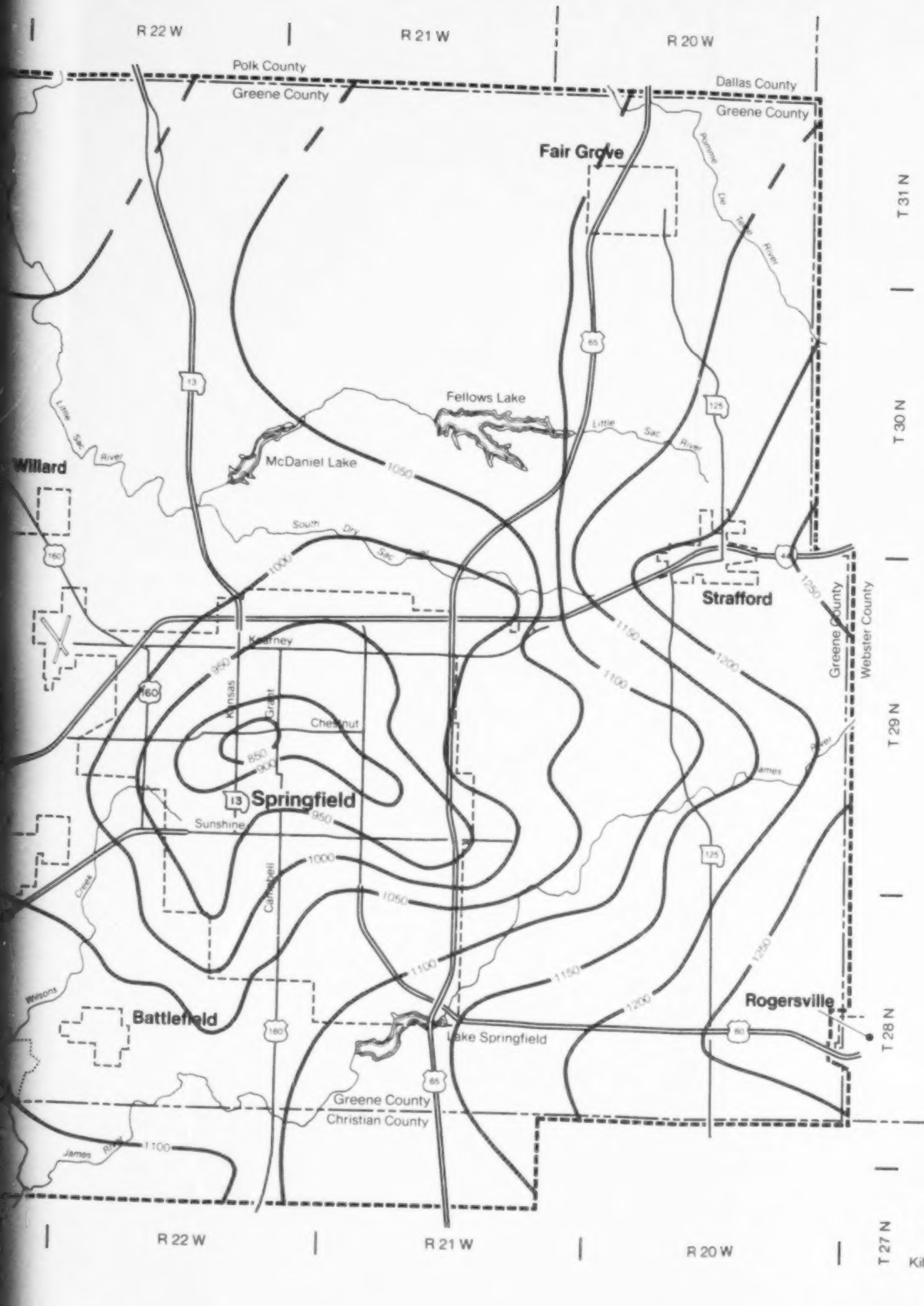
3. Surface-Underground Interactions

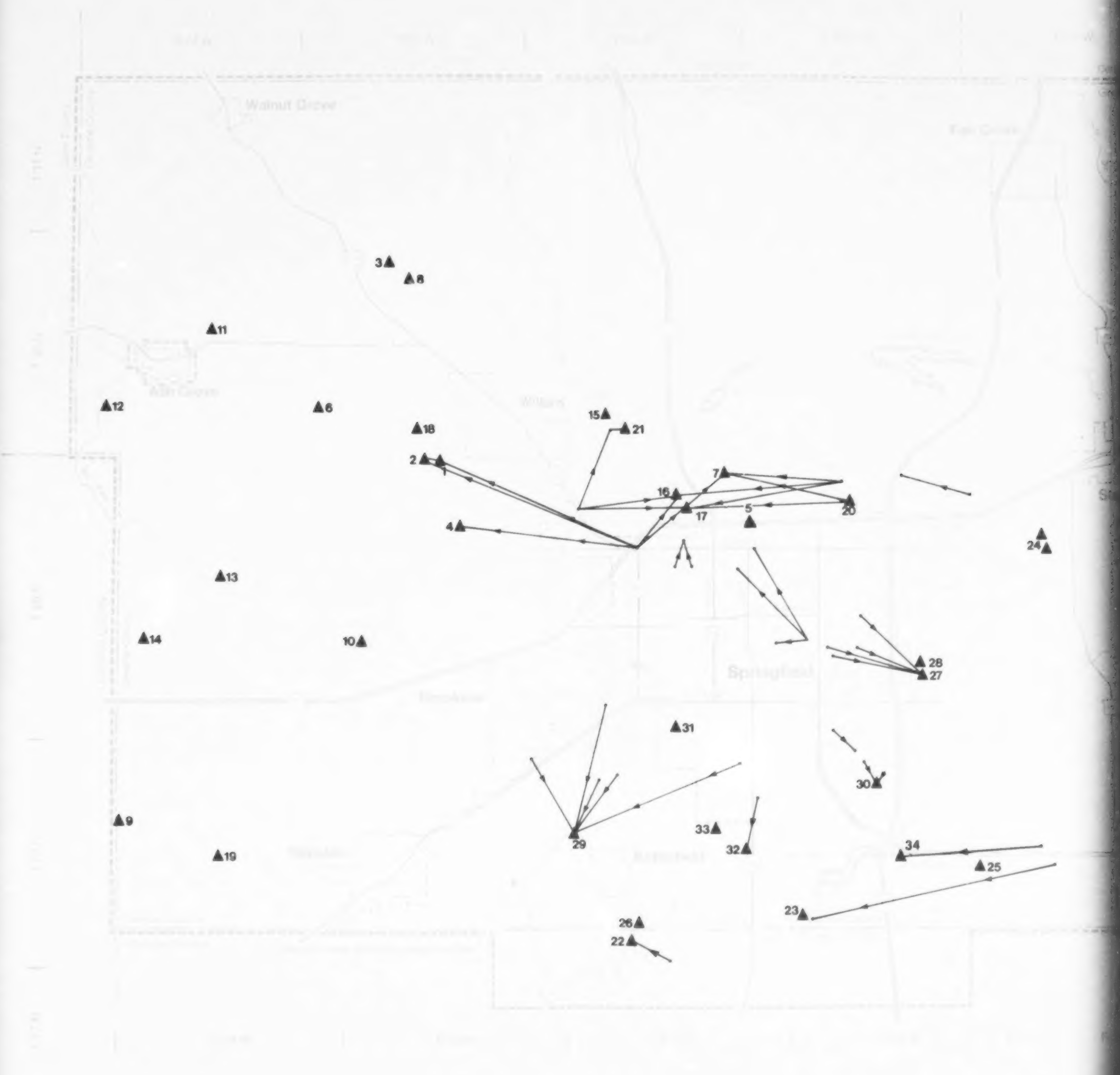
The ground water and surface waters are closely connected in Greene County. The streams recharge ground water during high flows, and


R 24 W
R 23 W
R 22 W
R 21 W
Polk County
Greene County
Walnut Grove
Fair Grove
Dade County
Greene County
T 31 N
1000
123
65
13
T 30 N
160
Ash Grove
Willard
Little Sac River
McDaniel Lake
Fellows Lake
Little
1050
South Dry Sac
1000
Sac River
1050
160
Kearney
950
Kansas
Grant
Chestnut
1150
1100
T 29 N
Lawrence County
Greene County
Sac River
850
900
Springfield
13
Sunshine
950
44
Brookline
1000
Campbell
1050
Wilsons Creek
13
60
1100
1150
T 28 N
Republic
Battlefield
160
Lake Springfield
65
Greene County
Christian County
Greene County
Christian County
Wilsons Creek Battlefield National Park
James River
1100
T 27 N
R 24 W
R 23 W
R 22 W
R 21 W

Piezometric Surface of Deep Aquifer
June, 1974

Figure 11




Walnut Grove
Fair Grove
3
8
11
Ash Grove
12
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Willard
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21
18
2
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24
13
14
10
28
27
Springfield
Brookline
31
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Republic
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Battlefield
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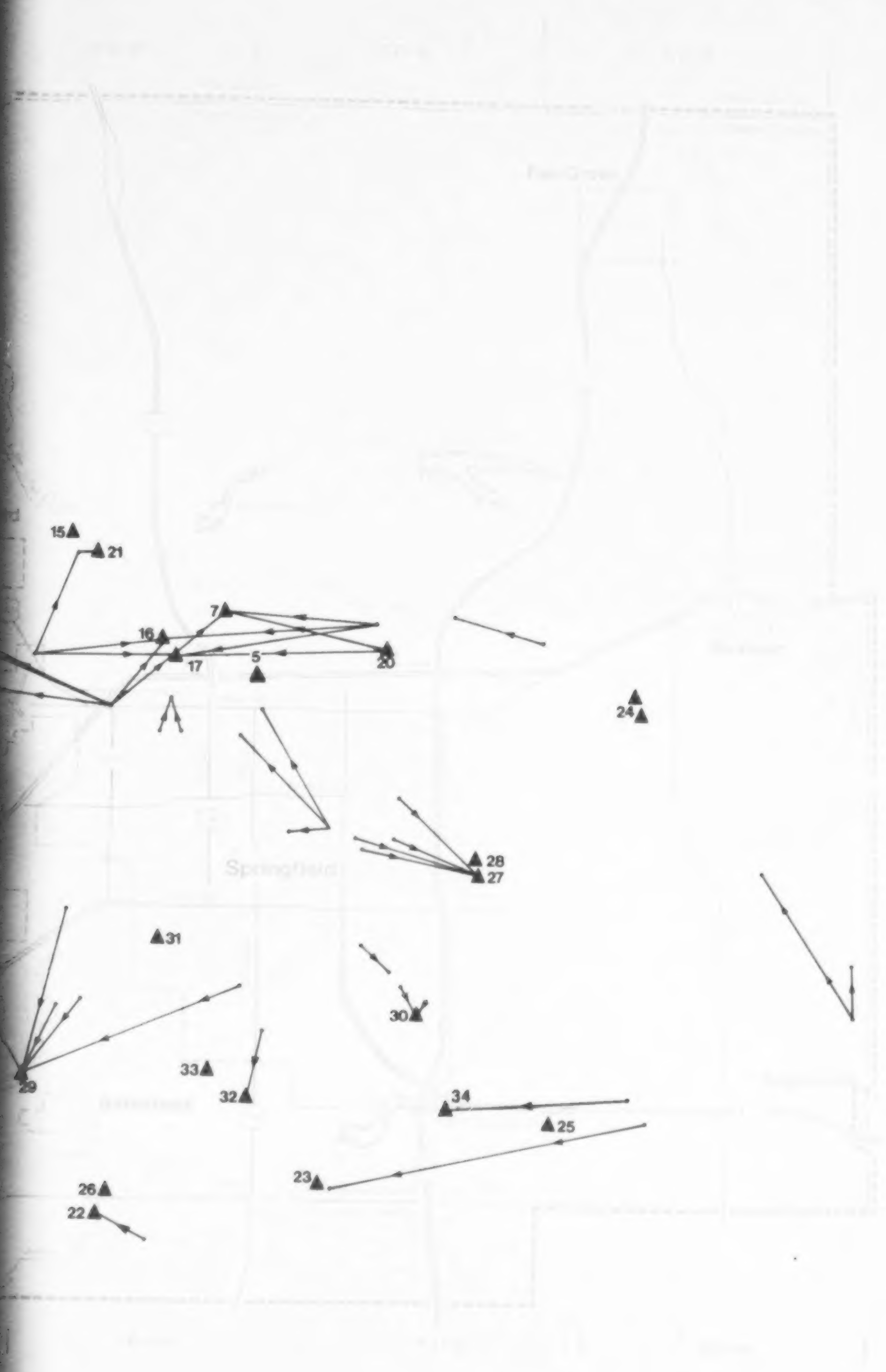
Springs And Studied Paths of Underground Water Movement

Figure 12



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the major streams are supplemented during drought periods by flows from springs. Sinkholes and other discrete recharge features also provide a direct connection between the surface and the upper aquifer.

a. Losing Streams. The flows in many Greene County waterways significantly decrease with distance downstream. These are termed "losing streams." While some authorities consider any stream with decreasing flow a losing stream, the MDNR defines a losing stream as one which distributes 30 percent or more of its flow into ground water by means of natural processes, such as through permeable soil and/or cavernous bedrock (50). These streams lose or gain flow depending upon the elevation of the water table relative to the position of the stream bed, and upon the permeability of the underlying rock. Where the rock is very permeable, the streams may completely disappear underground, and later reappear where the rock is less permeable (13). Pierson Creek, the South Dry Sac River, and Terrell Creek have been shown to have reaches where the flow is completely lost to the bedrock (13). Other losing streams include portions of the South Fork Pomme de Terre River and Clear, Wilsons, South, Pond, Pickerel, Asher, Sugar, Shuyler, Broad, and Davis creeks. Streams which meet the MDNR definition are given in Table 4 and losing reaches of streams are shown on Figure 9.

b. Springs. Springs abound in the planning area, as is typical of karst regions. The springs issue from Mississippian carbonate rocks and are second in size and number only to those of the Salem Plateau area to the east. Two types of springs, seepage and fracture, are found, as previously described in Section II-A. The major springs are listed in Appendix B - Table B-2 and shown on Figure 12.

Springfield obtains about ten percent of its water supply from the Valley Water Mills-Fulbright Spring system. Sander Spring at the head of Valley Water Mills reservoir is the chief contributor to the reservoir. Solution along joints and fault surfaces has created an interconnected underground drainage system for a distance of over four miles westward from the reservoir. Water from the reservoir is piped west to a joint fissure in the south bluff of South Dry Sac Creek and reappears at Fulbright Spring, some three miles west. Some of the water

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TABLE 4
LOSING STREAMS IN GREENE COUNTY

Name of Stream	Approximate Length (miles)	Stretch From	To
	OSAGE-GASCONADE RIVER BASIN		
S. Dry Sac River[a]	8	Headwaters	Mouth
Pickerel Creek[a]	12	Headwaters	Mouth
Sac River[a]	5	Hwy. 266	Hwy. F
Turkey Creek[b]	0.5	North of Walnut Grove	
Sugar Creek[b]	2	South of Walnut Grove	Mouth
So. Fork Pomme de Terre River[b]	1	Headwaters	
Branch of So. Dry Sac River[b]	1	West of Strafford	
Mt. Pleasant Branch[b]	0.5	Near Headwaters	
Asher Creek[b]	1	Headwaters	
Asher Creek[b]	0.5	At Cave Spring	
Branch of Little Sac River[b]	0.5	East of Willard	
Pond Creek[a]	1	Headwaters	
Pond Creek[a]	2.5	Hwy N Mouth	
Dry Branch[b]	5	Republic Plant	Mouth
	WHITE RIVER BASIN		
Wilsons Creek[a]	14	Headwaters	Christian Co. Line
Davis Creek[b]	10	Headwaters	Mouth
Broad Creek[b]	8	Headwaters	Mouth
Pierson Creek[b]	1	Headwaters	
Pierson Creek[a]	0.25	So. of Cherry Street	
Branch of James River[b]	0.75	Near Battlefield	
Terrell Creek[a] (Christian County)	0.5	Near Terrell	
McElhaney Branch[b]	3	Near Brookline	Mouth

TABLE 4 (Continued)
LOSING STREAMS IN GREENE COUNTY

Name of Stream	Approximate Length (miles)	Stretch From	Stretch To
WHITE RIVER BASIN (Cont.)			
Shuyler Creek[b]	4	Near Republic	Mouth
Turner Creek[b]	3		

Note: This table includes only those streams meeting the MDNR definition of a losing stream (see text).

Sources:

[a] (50).

[b] Site specific investigations by the Division of Geology and Land Survey, MDNR.

piped into the fissure continues underground and emerges at Ritter Springs, slightly more than one mile southwest of Fulbright Spring.

C. WATER QUALITY AND AQUATIC ECOLOGY

1. Surface Water Quality

The quality of the surface water and ground water of an area is an integral part of its natural environment, and, in turn, its human environment. The consequences of not protecting water quality can be very serious. Some pollutants, including various toxic chemicals, are not effectively removed by conventional drinking water treatment systems and may pose a threat to health. Contamination with bacteria, viruses, and other pathogenic organisms may result in water-borne disease outbreaks if treatment is inadequate. Many public and private well supplies receive little or no treatment and thus rely on the purity of the water source. Water treatment costs rise as additional treatment processes are required to remove pollutants from the water supply source. In addition to municipalities, many industries, from food processers to power plants, require a dependable source of clean water for use in production processes and for cooling. Most fish and wildlife species cannot survive in areas where the water is severely polluted. Recreational opportunities can also be curtailed.

a. Surface Water Quality Standards. The Missouri Clean Water Commission regulations categorize the state's waterways by type and use, as required by the Clean Water Act of 1977. These waters are protected from man-made sources of pollution by water quality standards. Classified Missouri surface waters are categorized as either Class P, P1, or C, as described below (50):

Class P:	Streams that maintain permanent flow even in drought periods.
Class P1:	Standing-water reaches of Class P streams, including impoundments.
Class C:	Streams that may cease flow in dry periods, but maintain permanent pools which support aquatic life.

The protected beneficial water uses defined by the standards are irrigation, livestock and wildlife watering, protection of warm-water aquatic life, cold-water sport fishery, whole-body contact recreation, drinking water supply, industrial process and cooling water, commercial fishery, and boating and canoeing (50). Table 5 displays the classes and uses of surface waters in Greene County. Wilsons Creek has no designated uses because at the time the standards were promulgated, its water quality was too poor to support any beneficial uses. The subsequent upgrading of Springfield's Southwest Treatment Plant has improved the water quality of Wilsons Creek to an extent that the state considered revising the designated use to include protection of aquatic life, but studies were not completed prior to the promulgation of revised water quality standards (53).

The standards contain water quality criteria to ensure that the established water uses are not violated. Water quality criteria are divided into general and specific criteria. General Criteria are applicable to all waters of the state at all times. They require that all waters be:

(a) free from substances in sufficent amounts to cause the formation of putrescent, unsightly, or harmful bottom deposits, or interfere with beneficial uses;

(b) free from oil, scum, and floating debris in sufficient amounts to be unsightly or interfere with beneficial uses;

(c) free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or taste, or interfere with beneficial uses; and

(d) free from substances or conditions that have a harmful effect on human, animal, or aquatic life.

Specific criteria apply to Class P, P1, and C waters for the particular protected water uses. An example of a specific criterion is the fecal coliform water quality standard of 200 organisms per 100 ml to protect waters used for whole-body-contact recreation. Another is the dissolved oxygen (DO) standard of 5 mg/l for protecting aquatic life. For Wilsons Creek, only the general criteria apply, since it has no

TABLE 5
WATER QUALITY CLASSIFICATIONS AND USES FOR STREAM ZONES

Stream	Zone[a]	Location	Length (mi)	Class	Uses[b]
OSAGE-GASCONADE RIVER BASIN					
Sac River	4	S1, T31N, R2W, Dade Co., to Farm Rd. 128 in S15, T29N, R24W	32.5	P	L, A, B, BC
Sac River	5	Farm Rd. 128 in S15, T29N, R24W, to center of S19, T29N, R23W	3	C	L, A
Little Sac River	2	Co. rd. in S11, T32N, R24W, Polk Co., to McDaniel Lake Dam	29	P	L, A, B
McDaniel Lake	3	Dam to S19, T30N, R21W	3	P1	L, A, D
Little Sac River	4	S19, T30N, R21W, to Fellows Lake Dam	4	C	L, A
Fellows Lake	5	Dam to Center S19, T30N, R20W	2	P1	L, A, B, D
Little Sac River	6	Center of S19, T30N, R20W, to center of S21, T30N, R20W	2	C	L, A, B
Fulbright Spring Branch	1	Mouth to S2, T29N, R22W	3	P	L, A, D
Pomme de Terre River	4	S24, T35N, R23W, Polk Co. to S7, T30N, R18W, Webster Co.	62	P	L, A, B, BC
Little Pomme de Terre River	-	Mouth, Polk Co. to Hwy CC	6	C	L, A
North Dry Sac River	1	Mouth of S15, T31N, R22W	3.5	P	L, A

(a) Stream segment, as defined by MDNR
(b) A = Aquatic life   IN = Industrial
B = Boating   IR = Irrigation
BC = Body Contact   L = Livestock, Wildlife
D = Drinking

TABLE 5
WATER QUALITY CLASSIFICATIONS AND USES FOR STREAM ZONES (Cont'd)

Stream	Zone(a)	Location	Length (mi)	Class	Uses(b)
		OSAGE-GASCONADE RIVER BASIN (continued)			
North Dry Sac River	2	S15, T31N, R22W to 519, T31N, R21W	4.5	C	L, A
Tributary	1		4	P	L, A
Tributary	1		2	P	L, A
South Dry Sac River	1	Mouth to 536, T29N, R22W	1.5	P	L, A
Mutton Hollow	1	Mouth, Polk Co. to 514, T31N, R20W	2	P	L, A
		WHITE RIVER BASIN			
James River	2	Hwy. U, Stone Co. to Lake Springfield dam	26	P	IR, L, A, B, D
Lake Springfield	3	Dam to Hwy. 60	2	P1	L, A, B, IN
James River	-	Hwy. 60 to S23, T29N R17W, Webster Co.	35	P	L, A, B, BC
Wilsons Creek	1	Mouth to Hwy. 88	14	P	--
Ward Branch	-	Mouth to Hwy. 160	2.5	P	L, A
Pierson Creek	-	Mouth to 55, T29N, R20W	7	P	L, A
Turner Creek	-	Mouth to S33, T29N, R20W	4	P	L, A
Sawyer Creek	-	Mouth to S12, T28N, R20W	5	P	L, A
Davis Creek	-	Mouth to S12, T29N, R20W	1	P	L, A
Davis Creek	-	S12, T29N, R20W to S1, T29N, R20W	3	C	L, A

(a) Stream segment, as defined by MDNR

(b)
A = Aquatic life IN = Industrial
B = Boating IR = Irrigation
BC = Body Contact L = Livestock Wildlife

protected uses. Specific criteria for surface water and ground water are given in MDNR regulations.

In order to meet the appropriate water quality standards, the Clean Water Commission also sets effluent quality regulations for point-source discharges to surface waters. The effluent limitations are specified in a permit for each point source of pollution and depend upon the nature and use of the receiving water body. The minimum discharge requirements are based upon conventional secondary treatment, but more stringent requirements apply to discharges to losing streams, lakes and reservoirs, and waters classified for whole body recreation. The effluent limitations, as summarized in Table 6, reflect more restrictive BOD and SS requirements for discharges to losing streams and lakes and reservoirs, and add fecal coliform limitations for losing streams and whole-body-recreation waters. In addition, more stringent limitations may be established in permits to prevent violation of water quality standards (50). For example, Springfield's two municipal treatment plants discharge to losing streams, but are required to meet effluent quality standards even stricter than those for losing streams to remain within the amount of waste loading that the streams can assimilate. These limitations are determined by special waste load allocation studies.

b. Existing Surface Water Quality.

1) Monitoring Stations. Water quality and quantity monitoring is conducted by the U.S. Geological Survey (USGS), in cooperation with the MDNR, Divisions of Geology and Land Survey and of Environmental Quality, and the City of Springfield. Their data are published in annual reports. There are no USGS monitoring stations in the Greene County portion of the Osage watershed, but there are stations on the Sac, Little Sac, and Pomme De Terre rivers downstream (north) of Greene County. In the Greene County portion of the White River basin, Wilsons Creek and the James River are both extensively monitored by the USGS as part of a long-range study of the effects of the Southwest municipal wastewater treatment plant and of Springfield urban runoff

TABLE 6
SUMMARY OF EFFLUENT REQUIREMENTS
(monthly average/weekly average)

Discharges to any stream: (except losing, protected, or wild and scenic rivers)

BOD (mg/l)	30/45
SS (mg/l)	30/45
SS (mg/l)	60/80 (for facultative treatment lagoon)
pH	6.9 to 9.0

Discharges to a lake or reservoir:

BOD (mg/l)	20/30
SS (mg/l)	20/30
pH	6.0 to 9.0

Discharges to a losing stream: (not permitted unless effluent removal is not technically feasible and aquifer water recharge limitations are met)

BOD (mg/l)	10/15
SS (mg/l)	15/20
pH	6.0 to 9.0
Fecal Coliform (per 100 ml)	200

Discharges to streams, lakes, and reservoirs identified as whole body contact areas:

Fecal Coliform (per 100 ml)	200

upon Wilsons Creek and the James River. At present there are four monitoring stations operating on the James River and two on Wilsons Creek. The two on Wilsons Creek continuously monitor several water quality parameters. Monthly water quality samples are taken at another station on the James River. Figure 9 shows monitoring stations on Wilsons Creek and the James River in the project area, and the type of sampling conducted at each (38).

2) White River Basin.

a) Historical Conditions. Before 1978, the White River basin streams immediately downstream of Springfield had poor overall water quality. Wilsons Creek was severely degraded (40); water quality standards were consistently violated (13); and to the casual observer, the creek appeared "dark in color, gave off an offensive odor, and was unable to support any aquatic life" (54). The creek was so polluted it offended visitors to the Wilson's Creek Battlefield Park. Pollution of Wilsons Creek also had an adverse effect on the James River. A 1977 study by the USGS concluded that there were significant differences in certain water quality parameters in the James River between stations upstream and downstream of Wilsons Creek. These parameters included dissolved oxygen (DO), specific conductance, total nitrogen, total phosphorus, and dissolved solids (55). The degradation of the James was apparent for at least 14 miles south of its confluence with Wilsons Creek (40, 56). Water quality standards for DO, ammonia, nitrogen, and fecal coliforms were frequently violated in the James River (13, 36). Several fish kills had occurred in the James River in Christian County, downstream of the planning area (57).

At the time of these poor water quality conditions, the major sources of pollutants to Wilsons Creek were Springfield's Southwest Wastewater Treatment Plant and the city's storm runoff. The latter was the major cause of the fish kills. The most severe fish kills happened when storms over Springfield occurred during low-flow periods on the James River. These storms discharged large flows of polluted water to Wilsons Creek and the James River, causing sudden depletions of dissolved oxygen. These large flows also scoured wastewater sludge deposits from the bottom of Wilsons Creek, contributing to fish kills by further increasing the organic load and decreasing the dissolved oxygen content (57). The temperature of the runoff may also have been a factor, causing thermal shock when fish encountered the heated runoff from asphalt and concrete surfaces (39).

While Springfield's urban runoff caused significant, short-term degradation of Wilsons Creek and the James River, the Southwest Treatment Plant contributed the greater mass of pollutants over a long period of time (56). These pollutants included ammonia and nitrate-nitrogen, phosphates, sulfates, and bacteria (56). Much of the Southwest plant effluent flowed directly into nearby sinkholes and later emerged at Rader Spring. The discharge of Rader Spring to Wilsons Creek also degraded the creek's quality further downstream (40, 58). The sinkholes at the Southwest plant were subsequently sealed artificially, which improved Rader Spring's water quality and diminished its impact on Wilsons Creek (8, 40).

b) Existing Conditions. The water quality of Wilsons Creek and the James River dramatically improved after the Southwest Treatment Plant was upgraded in 1977 (36, 54). The USGS in 1980 concluded that, under normal flow conditions, there are no statistically significant differences in water quality between the stations on Wilsons Creek upstream and downstream of the Southwest Plant (59). Sludge deposition in Wilsons Creek downstream of the plant was eliminated when the plant was upgraded (60).

Nevertheless, water quality standards are still violated. During storms, polluted urban runoff and infrequent bypass flows from the Southwest Treatment Plant are carried into Wilsons Creek (60). Phosphate, which is not removed by the Southwest plant, is still present at high levels in the James River downstream of its confluence with Wilsons Creek, as is nitrate, a treatment process by-product.

Areas of the James River upstream of Wilsons Creek within the planning area have generally good water quality, except for organic enrichment of Pierson Creek evidenced by high nitrate levels, and degraded conditions near Sequiota Spring (56). City Utilities sampled the James River east of Springfield and concluded that the water quality was comparable to that of the Little Sac River watershed from which the city's water supply has been taken (see Table 7). In 1980, with the completion of the Blackman Water Treatment Plant and the intake structure below Pierson Creek, the James River is now an additional source of drinking water for Springfield (62).

The Springfield-Greene County Health Department initiated in August 1980 a year-long program to sample Sawyer Creek. A total of four springs and four stream sites were sampled monthly and analyzed for fecal coliform:fecal streptococci ratios and lead, copper, chromium, zinc, and iron concentrations. Results demonstrated low concentrations of metals. Fecal coliform:fecal streptococci ratios indicated bacteria of natural or agricultural origin at all stations except those near the Oak Crest Mobile Home Park, which uses septic tanks to treat its wastewaters (63, 64).

3) Osage River Basin. The Osage River basin streams in Greene County are affected by fewer water quality problems than the White River basin portion of Greene County. Two Osage River basin impoundments (McDaniel Lake and Fellows Lake) are used as sources of Springfield's drinking water and are of good quality, although an unusual occurrence of taste and odor problems was experienced in September, 1982.

Water quality problems in the Little Sac River basin in Greene County are caused by discharges from Springfield's Northwest Wastewater Treatment Plant and by leachate from abandoned landfills in the floodplain of the Little Sac River. For example, water quality standards for DO and ammonia are periodically exceeded in the South Dry Sac and Little Sac rivers. Also, diurnal DO fluctuations caused by algal growth and high nutrient levels have been recorded (36, 65). The impact of the Northwest plant's effluent is more significant than that of the landfill leachate and is greatest during low stream flows, whereas the impact of the seepage from the landfill is greater during higher flows. Seepage from the landfills is discussed further in Section II-M.

TABLE 7

CHARACTERISTICS OF SPRINGFIELD'S DRINKING WATER SUPPLY SOURCES

Parameter	James River Near Blackman Intake[a]	Other Sources[b]
Manganese (Mn^{+2}) (mg/l)	0	0.08
Nitrate (NO_3^-) (mg/l)	1.5	4.9
Total Alkalinity as $CaCO_3$ (mg/l)	152	149
Total Hardness as $CaCO_3$ (mg/l)	165	164
pH	7.62	7.30
Conductivity (micromhos/cm)	281	327

(a) Average of samples taken October, 1976 through February 1978

(b) Combined sample taken December 14, 1979, from Fulbright Spring, McDaniel Lake, and Fellows Lake. Other analyses for pesticides and heavy metals indicated no problems with generally non-detectable levels.

Sources: (42, 61)

There have been fish kills in the Little Sac River and in Pea Ridge Creek, a South Dry Sac tributary. Suspected causes include landfill leachate, Northwest Treatment Plant effluent, and stormwaters and sewage bypassed by the Northwest Plant (66, 67). Refer to Section II-C-4 for a more detailed discussion of fish kills in the planning area.

c. Point Sources of Pollution. A point source is defined by the Clean Water Act of 1977 as "any discernible confined and discrete conveyance...from which pollutants are or may be discharged" (68). The Missouri Clean Water Commission sets effluent standards for point-source discharges to prevent the violation of water quality standards for the receiving stream. A permit is issued for each point-source discharge, which defines its applicable effluent standards and the required discharge sampling frequency. The permits are known as National Pollutant Discharge Elimination System (NPDES) permits and are issued by the MDNR.

1) Municipal. There are five publicly-owned municipal wastewater treatment facilities in the planning area, four of which are operated by the City of Springfield (see Table 8). The Northwest and Southwest plants serve the city's population and are the most significant individual point sources in the area. Other plants serve the Lakewood Village and Sunburst Hills subdivisions. With the 1982 completion of the new Airport Trunk and Pump Station conveying wastes to the Northwest plant, the septic system that previously served the airport has been retired. The Southwest and Lakewood Village and Sunburst Hills plants discharge into the White River basin, while the Northwest plant, and plants at Ash Grove and Republic, discharge into the Osage River basin. All of these facilities have periodically failed to meet their NPDES permit standards (1, 69). These failures often occur during storms, when inflow to their collection sewer systems cause the facilities to become hydraulically overloaded.

There are 21 other domestic, commercial, and institutional wastewater point sources in the planning area, serving mobile home parks, schools, subdivisions, shopping centers, and other developments

TABLE 8
MUNICIPAL POINT SOURCE DISCHARGERS

Facility	Design Flow (mgd)	Receiving Stream	Permit Limits[(a)(b)]		Treatment
			Item	Day/Wk/Mo	
OSAGE RIVER BASIN					
Ash Grove Treatment Facility (not in planning area)	0.33	Tributary of Sac River	BOD SS	30/-/- 30/-/-	Oxidation ditch, Clarifiers
Northwest Wastewater Treatment Plant, Springfield	3.5	Pea Ridge Creek and Little Dry Sac Creek	BOD SS FC DO[(c)]	15/-/- 15/-/- 200/-/- 6.0/-/-	Primary treatment, aeration and reaeration tanks, final clarifiers, chlorination
Republic Municipal Wastewater Treatment Facility	0.75	Pickerel Creek	BOD SS	30/-/- 30/-/-	Contact stabilization plant, 3-cell lagoon, chlorination
WHITE RIVER BASIN					
Lakewood Village Subdivision, Springfield	0.06	Tributary of Lake Springfield	BOD SS FC	-/30/20 -/30/20 200/-/-	Contact stabilization plant, chlorination
Southwest Wastewater Treatment Plant, Springfield	30	Wilsons Creek	BOD SS FC Ammonia	10/-/- 10/-/- 200/-/- 2/-/-	Primary treatment, pure oxygen aeration, secondary clarification, nitrification, final clarification, filtration, ozonation
Sunburst Hills Subdivision, Springfield	0.015	Tributary of Lake Springfield	BOD SS FC	-/45/30 -/45/30 200/-/-	Ext. aeration plant, chlorination, dechlorination

(a) Most permits also limit pH within the range of 6.0 to 9.0.

(b) BOD - biochemical oxygen demand (mg/l); SS - suspended solids (mg/l); FC - fecal coliform (per 100 ml); DO - dissolved oxygen (mg/l); Ammonia (mg/l).

(c) Minimum DO of 6.0 mg/l or 80% of saturation, whichever is least.

(see Table 9). Seven of these are located in the Osage River watershed, and the remainder are in the White River watershed. Most treat their wastes in aerobic lagoons or small aeration plants. Many of the facilities have periodically failed to meet their NPDES effluent limitations. Operation and maintenance deficiencies are also problems at many (1, 69). None of these alone are a significant individual point source of discharge, but collectively they contribute to the localized degradation of the area's surface and ground waters.

2) Industrial. Twelve industries discharge directly to surface waters in the planning area (see Table 10). Most of the industries discharge cooling waters and are located in the White River basin.

The industries have generally been in compliance with effluent requirements. The Springday Company of Dayco Corporation was included in a controversial list of 13 individual sites posing danger to Missouri ground water supplies (70). The list was drawn from an EPA study which was not intended to characterize individual sites, and thus does not provide sufficient evidence to infer that the Springday Company is polluting Greene County ground waters. The Springday Company discharges only cooling water into its lagoon (72), and was in compliance with its NPDES permit limitations.

d. Nonpoint Sources of Pollution. Nonpoint pollutants are defined as "any material for which no NPDES permit can be issued, which enters waters of the state and is detrimental to the uses for which that water has been designated" (73). Studies of Springfield area surface waters in both drainage basins have indicated that nonpoint sources are significant, if undefined (39, 74). While most nonpoint pollutant sources have their biggest impact on surface waters during storms, several sources also discharge pollutants in continuous, unmeasurable amounts. The major sources of nonpoint pollutants in Greene County may be classified as urban, agricultural, or industrial.

Urban nonpoint sources of pollutants include uncollected stormwater runoff, effluent from septic tanks, and seepage from domestic wastewater treatment lagoons. (While the latter two are actually dis-

TABLE 9
DOMESTIC, INSTITUTIONAL, AND COMMERCIAL POINT SOURCE DISCHARGERS

Facility	Design Flow (mgd)	Receiving Stream	Permit Limits (a)(b) Item	Permit Limits (a)(b) Day/Wk/Mo	Treatment
OSAGE RIVER BASIN					
Fair Grove School	0.024 (0.026 actual)	Tributary of Pomme de Terre River	BOD SS	45(c)/-/- 30(c)/-/-	Septic tank, sand (rock) filter, laterals
Hood's Service Center (I-44 & Hwys PP and K)	0.0057	Tributary of Pickerel Creek	BOD SS	30/-/- 30/-/-	2-cell lagoon, (No discharge reported)
Lakewood Mobile Home Park (being connected to Springfield system)	0.020	Tributary of Dry Sac Creek	BOD SS FC	-/45/30 -/45/30 200/-/-	1-cell lagoon, ext. aer. plant, chlorination
Springfield "44" Auto/ Truck Stop (Strafford)	0.013	Tributary of Little Sac River	BOD SS FC	-/45/30 -/45/30 200/-/-	Holding basin, ext. aer. plant, 1-cell lagoon, chlorination
Willard Laundromat and Carwash	0.007	Tributary of Clear Creek	BOD SS	30/-/- 30/-/-	1-cell lagoon
Willard Retirement Village	0.0024	Clear Creek	BOD SS FC	5/1(c)/10(c) 10/20(c)/15(c) 200/-/-	Four home treatment units, open sand filters, chlorination, (two treatment units, sand filters, and chlorination being added)
The Willows Subdivision (near Republic)	0.045	Pond Creek	BOD SS FC	-/15/10 -/20/15 200/-/-	Ext. aer. plant, sand filter, chlorination
WHITE RIVER BASIN					
American Laundry (Springfield)	0.009287 (softener backwash)	South Branch of Jordan Creek	SS Sodium chloride	30/-/20	None

TABLE 9 (Cont'd)
DOMESTIC, INSTITUTIONAL, AND COMMERCIAL POINT SOURCE DISCHARGERS

Facility	Design Flow (mgd)	Receiving Stream	Permit Limits		Treatment
			Item	Day/Wk/Mo	
Coronado Mobile Home Park (Springfield)	0.0158	Sequiota Branch	BOD SS	30/-/- 30/-/-	1-cell lagoon (usually no discharge reported)
English Village Park (Christian County)	0.08025	Tributary of James River	BOD SS	-/45/30 -/45/30	Ext. aer. plant, chlorination
Federal Medical Center (Springfield)	0.016 (Softener regenerant)	South Creek	Set S Chloride	0.3/-/0.3 375/-/250	None
General Council of Asemblies of God (Springfield)	0.18 (Cooling Water)	Jordan Creek	Temp	90/-/-	None
Hi-View Mobile Home Park (Sewer District formed and petitioned for connection to Springfield - Wilsons trunk)	0.039	Wilsons Creek	BOD SS FC	5/-/- 10/-/- 200/-/-	1-cell lagoon
Hickory Hills Country Club	0.010	Tributary of Pierson Creek	BOD SS FC	-/15/10 -/20/15 200/-/-	Ext. aer. plant sand filters, chlorination
Holyoke Park Subdivision	0.0044	Workman Branch	BOD SS FC	-/15/10 -/20/15 200/-/-	Ext. aer. plant, sand filter, chlorination (No discharge reported)
Ozark Park-A-Home (Under litigation with MoDNR)	0.045	Tributary of Ward Branch	BOD SS FC	5/-/- 10/-/- 200/-/-	2-cell lagoon
Prairie View Heights Subdivision	0.050	Tributary of Wilsons Creek	BOD SS FC	5/-/- 10/-/- 200/-/-	Ext. aer. plant, pressure filter, chlorination

TABLE 9 (Cont'd)
DOMESTIC, INSTITUTIONAL, AND COMMERCIAL POINT SOURCE DISCHARGERS

Facility	Design Flow (mgd)	Receiving Stream	Permit Limits Item	Permit Limits Day/Wk/Mo	Treatment
St. John's Regional Center (Springfield)	0.002 (Softener regenerant)	Fassnight Creek	Set S Chloride	0.3/-/0.2 375/-/250	None
Timbercrest Mobile Home Park (Springfield)	0.0269	Thompson Branch	BOD SS	-/45/30 -/80/60	2-cell lagoon (Little or no discharge)
Village Subdivision	0.045	Wilsons Creek	BOD SS FC	-/15/10 -/20/15 200/-/-	Ext. aer. plant, filter, chlorination
Wilson's Creek National Battlefield Park	0.015	Wilsons Creek	BOD SS FC	-/15/10 -/15/10 200/-/-	Chemical add'n, mixing, flocculation, clarification, carbon adsorption, pressure sand filtration, chlorination

(a) Most permits also limit pH within the range of 6.0 to 9.0.

(b) BOD - biochemical oxygen demand (mg/l); SS - suspended solids (mg/l); Set S - settleable solids (mg/l); FC - fecal coliform (per 100 ml); Temp - temperature (°F); Chloride (mg/l).

(c) Proposed permit limit.

TABLE 10
INDUSTRIAL POINT SOURCE DISCHARGERS

Facility	Design Flow (mgd)	Receiving Stream	Permit Limits(a)(b)		Treatment
			Item	Day/Wk/Mo	
OSAGE RIVER BASIN					
Griesemer Stone Co. (Springfield)	(Stormwater at quarry)	Tributary of South Dry Sac River	SS	75/-/50	None - Water pumped out
WHITE RIVER BASIN					
Ash Grove Cement (Springfield)	0.006-Cooling Water	Sequiota Creek	SS	-/45/30	-
			Set. S	-/0.3/0.2	
			O&G	-/20/15	
	0.001-Sanitary wastewater	Sequiota Ceek	BOD	-/45/30	Ext. aer. plant, chlorination
			SS	-/45/30	
			FC	200/-/-	
	Storm runoff-limit on oil emulsion for dust control				
Dayco Corporation Springday Co., (Springfield)	-	South Creek	SS	30/-/-	Settling basin, oil skimmer
			O&G	10/-/-	
			Temp.	90/-/-	
General Electric	0.625 Cooling water and boiler blowdown	Tributary of Galloway Branch	SS	45/-/30	-
			Temp.	90/-/-	
James River Power Plant	135 Once-through cooling water	Lake Springfield	Chlorine	0.5/-/0.2	-
			Temp	100/-/100	
	3.0 Ash pond overflow		SS	100/-/30	-
			O&G	20/-/15	
	- By-pass		Chlorine	0.5/-/0.2	-
Kraft Foods Co. (Springfield)	0.1695 Cooling and boiler blowdown (0.1325 actual)	Fassnight Creek	SS(c)	45/-/30	-
			O&G(c)	20/-/15	
			Temp(c)	90/-/-	

TABLE 10 (Cont'd)
INDUSTRIAL POINT SOURCE DISCHARGERS

Facility	Design Flow (mgd)	Receiving Stream	Permit Limits		Treatment
			Item	Day/Wk/Mo	
Lily Division, Owens Illinois (Springfield)	0.0108 Cooling water	Tributary of Jordan Creek	O&G	15/-/-	-
			Temp	90/-/-	
			Surfactants	1/-/-	
Mid-America Dairymen, Inc. (Springfield)	0.180 Cooling water	Jordan Creek	SS	45/-/30	-
			Temp	90/-/-	
Paul Mueller Co. (Springfield)	0.070 Cooling water, average	Jordan Creek	COD	100/-/75	-
			Set S	0.3/-/0.2	
			O&G	20/-/15	
			Temp	90/-/-	
Southwest Power Station	Coal, limestone storage runoff	Tributary of Wilsons Creek	SS	50/-/-	(No discharge reported)
	0.68-Drains, ash transport, cooling		SS	100/-/30	-
			O&G	15/-/10	
			Chlorine	0.5/-/0.2	
			Temp.	100/-/95	
	Landfill leachate		SS	50/-/-	-
	Stormwater runoff		SS	50/-/-	-
Springfield Regional Stockyards	Stock trough overflow and runoff	Tributary of Wilsons Creek	BOD	-/15/10	-
			SS	-/20/15	
			FC	200/-/-	
Syntex Agribusiness, Inc. (Springfield)	0.104-Cooling water and boiler blowdown, average	Jordan Creek	SS	45/-/30	-
			Temp	-/-/90	

(a) Most permits also limit pH within the range of 6.0 to 9.0.
(b) BOD - biochemical oxygen demand (mg/l) SS- suspended solids (mg/l); Set S - settleable solids (mg/l); FC - fecal coliform (per 100 ml); O&G - oil and grease (mg/l); COD - chemical oxygen demand (mg/l); Temp - temperature (°F); Chloride (mg/l).
(c) Proposed permit limit.

crete sources, they are not covered by NPDES, and it is difficult to trace pollutants entering surface water and groundwater back to specific septic tanks or lagoons.) Urban stormwater runoff is the most significant of these. It contains high amounts of organics and suspended solids, and concentrations of a variety of metals and pesticides. These contaminants are carried into stormwater by "street refuse, such as dirt, litter, oil, disintegrated asphalt, and animal droppings; stagnant and septic water from storm sewer catch basins, ditches, and other depressions; and chemicals from many sources" (57, 75). Both solid waste and sludge landfills may be urban nonpoint sources of pollutants when they are located in areas of flooding or are improperly sealed (76). Several of the abandoned solid waste landfills for the City of Springfield are located in floodplains and leach pollutants (65, 66, 77).

Stormwater runoff has been shown to have a severe, acute impact on Wilsons Creek and the James River. Surges of runoff were found to have caused fish kills in the James River downstream of Greene County (40, 57). However, much of the pollution was shown to be restricted to the initial flow of stormwater in Wilsons Creek (13), due to the coincidence of high water temperatures, high toxic chemical concentrations, and extremely low dissolved oxygen content (49).

Urban stormwater runoff is a major pollutant source in Greene County for a number of reasons. First, the area has undergone rapid development over the past few years, increasing the volume of runoff by increasing the amount of impervious (paved) surface. Urbanization also decreases the quality of stormwater runoff. Second, Springfield's urban runoff problems are aggravated by a stormwater sewer system that was constructed before a proper regard for land use and geology became an integral part of sewer planning (78). Third, the area's karst topography is not compatible to urbanization. The numerous sinkholes in the area tend to channel flows directly to the ground water until the sinkholes clog, at which time they flood. In addition to these effects of natural drainage, Springfield's stormwater drainage system was designed in the past to use sinkholes as artificial receptacles.

Improved land use planning practices will help avert such drainage problems in newly developed areas; however, present problems are likely to remain (78).

Septic tanks are sources of organic and bacterial pollutants in Greene County. They are significant where they are highly concentrated, such as near Springfield, and where geologic conditions are poor. In areas with sinkholes, rock fractures, or poorly permeable soils, the septic tank effluents are not sufficiently treated by percolation but are instead channeled directly to the ground or surface water (56, 76). Pierson and Sequiota Creeks have contained concentrations of coliform bacteria many times those concentrations expected from natural sources, with septic tank effluent the suspected cause (56).

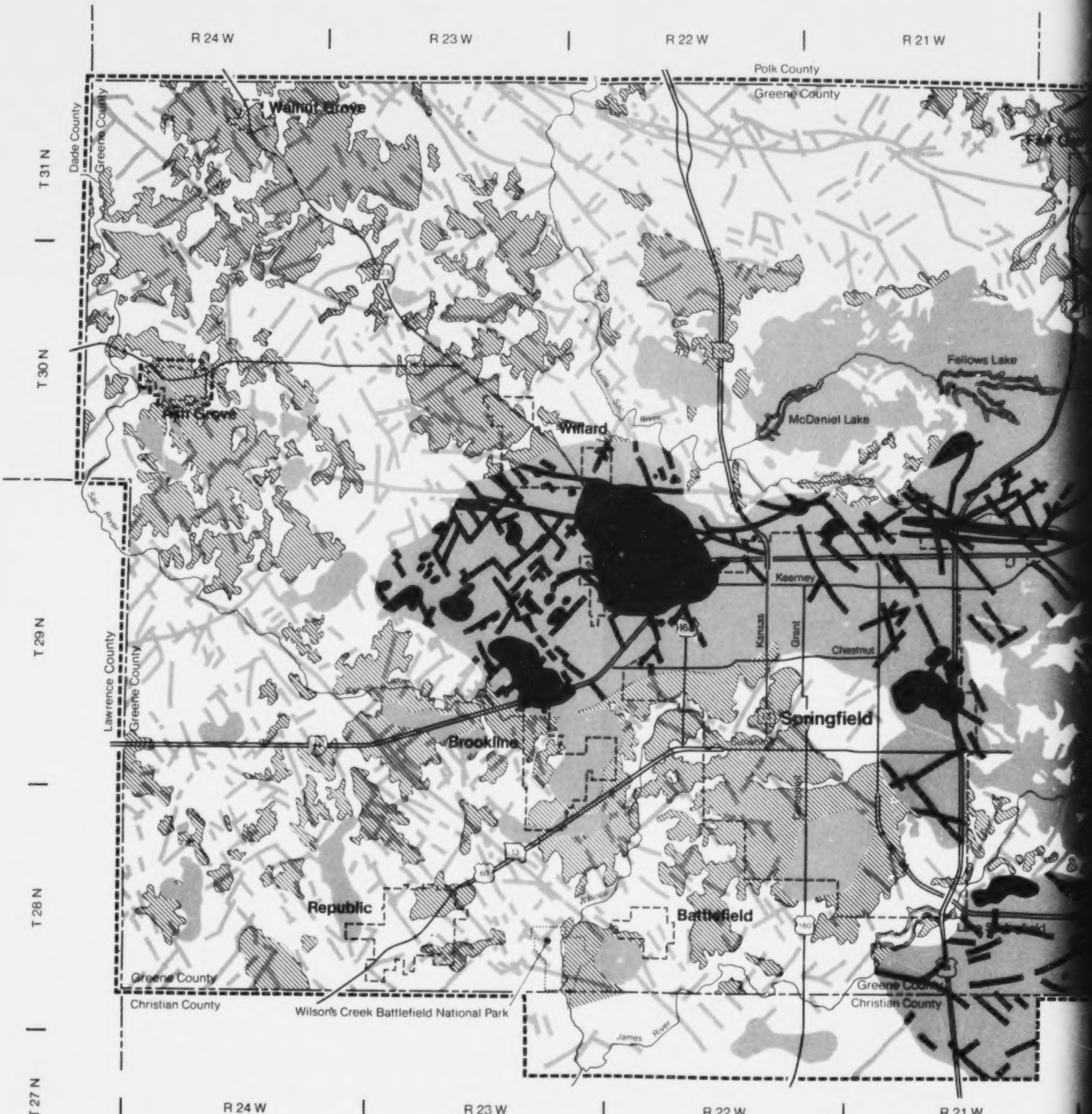
Agricultural sources are significant dischargers of pollutants to surface waters in outlying areas of Greene County. Agricultural runoff contributes high amounts of nutrients to the planning area's surface waters, particularly to the Little Sac River (65), causing excessive plant growth (73). A moderate level of bacterial contamination recorded for Sawyer Creek, a tributary of the James River, was found to originate from agricultural sources (79). There are a number of dairies and farms in the area that discharge their wastes into anaerobic lagoons designed to be nondischarging. Some of these "animal waste management facilities," as they are termed by the DNR, probably discharge pollutants to the local ground water and surface water (80).

Industrial sources sometimes discharge pollutants beyond those covered by their NPDES permits, through runoff, accidental spills, and improper design or operation of treatment facilities. Industrial runoff adds chemicals to urban runoff, and thus increases its impact on surface waters (76). Accidental spills of chemicals, particularly gasoline, have caused fish kills in the North Dry Sac and the Spring Branch (73). Spill prevention programs established by the industries, combined with increased cooperation between industries and the City of Springfield, have decreased the frequency of industrial chemical spills, although gasoline spills and leakages remain a problem (81, 82). Some industrial nondischarging lagoons discharge inadequately treated pollutants to ground waters and surface waters. These discharges are caused by poor treatment facility design, which either allows seepage through improperly sealed liners into the ground water or permits runoff into surface waters during storms (80).

Litton Industries, in particular, has been the focus of investigations and litigation to determine its contribution to ground water and surface water pollution (80). Litton's wastewaters, which contain high concentrations of ammonia and heavy metals such as copper, have percolated through ground water to emerge in the springs in Fantastic Caverns (83). Wastewater from a no discharge lagoon at Litton was reported, in the past, as being discharged directly into sinkholes adjacent to the lagoon. In the spring of 1982, leakage through the lagoon berms threatened collapse of the dikes. Under an emergency directive by MDNR, wastewater from this lagoon was spray-irrigated onto nearby land to alleviate the emergency. Litton closed the lagoon and disposed of the sludge at an approved hazardous waste facility (84).

2. Ground Water Quality

The danger of ground water pollution in karst regions is much greater than in areas protected by overlying impervious deposits or deposits capable of natural filtration. Flow velocity in karst is generally greater than in normal soils and bedrock, and thus contaminated water is not adequately filtered for self-purification. All of Greene County is affected by the water quality of its aquifers - those underground rock formations that contain the area's ground water. Industrial, municipal, and many private water supplies derive their water from aquifers. Urban growth has intensified the demand for high quality ground water and increased the possibilities for its contamination. For example, Springfield plans to develop an industrial park in an area that is extremely susceptible to contamination of ground water supplies (83, 85). The result of the increased urban development and the consequently greater demand for ground water is an increase in the number of contaminated wells and aquifers, or parts of aquifers, and in the potential for ground water contamination throughout the area (86, 87) (See Figure 13).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T 31 N
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Ash Grove
Willard
Little Sac River
Fellows Lake
McDaniel Lake
Kearney
Kansas
Grant
Chestnut
Springfield
Sunshine
Brookline
Lawrence County
Greene County
Sac River
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Republic
Battlefield
Wilson Creek
160
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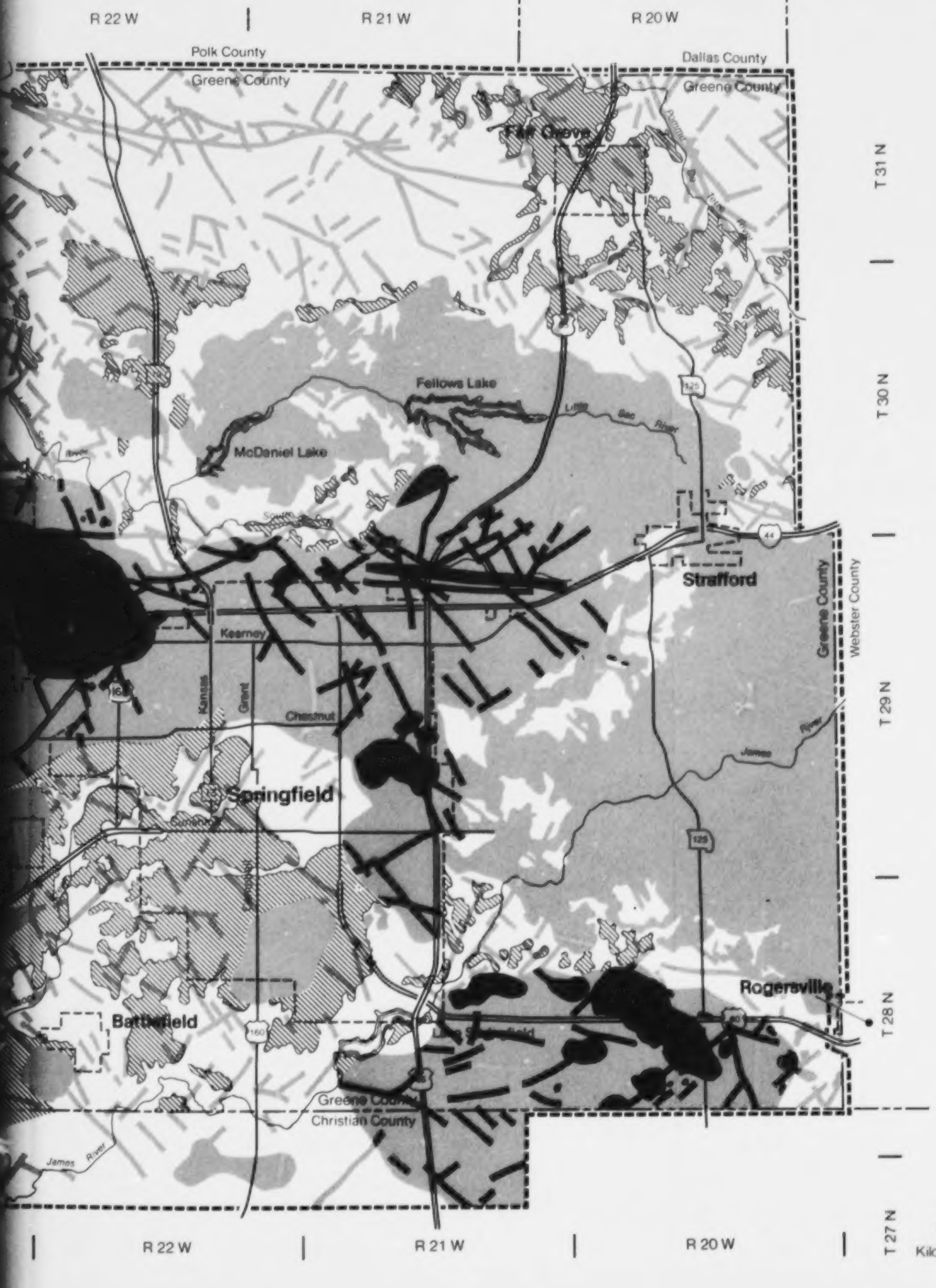

Groundwater Contamination Hazard Areas

Figure 13

Note:

Christian County information inferred from USGS maps and based on Aley & Thomson, 1980 rating system. Specific data not readily available.

The rated areas on this map have been generalized from several categories. The map should be used with caution, for planning purposes only in the broadest sense. For specific sites, additional study is advised.

Legend

☐	Low Hazard
▨	Moderate Hazard
▒	High Hazard
■	Extremely High Hazard

Source: (12)

Planning Area ▬ ▬ ▬ ▬
City Limits – – – – – –
County Limits – – —— –

a. Aquifers and Springs. The present quality of the ground water in the Springfield area may be described as generally good, but with localized contaminated areas (13). The entire area, however, is threatened with ground water contamination from municipal and industrial sources (86). Two aquifers in particular are becoming polluted, the "upper" or "shallow" aquifer, and the Swan Creek Sandstone member in the lower aquifer (3, 13, 86, 88). The upper aquifer consists of cherty limestones of Mississippian age. Numerous connections between this aquifer and the surface have developed by weathering and improperly constructed wells. These passageways allow rapid movement of surface water to the ground water. The Swan Creek Sandstone forms the upper layers of the lower aquifer and lies below the Northview Shale, which is the impervious layer separating the upper and lower aquifers (13). The Swan Creek Sandstone has been degraded by poorly constructed wells that allow surface contaminants to be transported into the ground water (86).

Wells that tap the shallow aquifer or the Swan Creek Sandstone aquifer are extremely susceptible to contamination. Many private wells in Greene County have been contaminated by pollution from such sources as urban and agricultural runoff, septic tank effluent, leachate from improperly sealed industrial and municipal wastewater treatment lagoons, and solid waste landfills (49, 52, 79, 80, 86, 89). In 1970, a study of 50 wells in Springfield found 42 percent with coliform levels over the drinking water standard of two organisms per 100 ml (86, 90). A 1974 study of 106 Springfield area private wells discovered 26 percent were similarly contaminated. According to the MDNR, 31.6 percent of the wells in Greene County were declared unsafe in 1977 (91, 92). Preliminary results from a MDNR study of the private wells in Greene County show that 20 percent of the wells are contaminated with coliforms (20). The number of contaminated wells discovered during the Springfield-Greene County Health Department's routine voluntary sampling of private wells varies between 25 and 30 percent (86, 93). Many of the private wells in the Springfield area are improperly built and cased, and penetrate the upper aquifer or the Swan Creek Sandstone. The areas of highest coliform concentrations in 1972 were wells in the west, northwest, south, and southeast areas of the city (88).

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With the exception of the Swan Creek Sandstone, the lower aquifer is relatively pure and is utilized by the largest private, industrial, and city public wells. The upper aquifer can be distinguished chemically from the lower aquifer in nonpolluted areas because of the different rock units that make up the aquifers. As described by the USGS (13),

> Water from wells open to the major [deeper] aquifer is of the calcium-magnesium-bicarbonate type, reflecting the chemical composition of the dolomite which makes up the major aquifer. Water from the minor [shallow] aquifer is generally of the calcium-bicarbonate type reflecting the composition of the limestone which makes up the minor aquifer. Water from the minor aquifer has a higher chloride, nitrate, and total dissolved solids concentration than water from the major aquifer.

The chemical quality of the county's spring water is similar to that of the shallow aquifer, because of the many interconnections between the springs and the shallow aquifer. The chemical quality of water from the deep aquifer becomes nearly identical to that of the shallow aquifer in urban areas such as Springfield where both are present. Since the shallow aquifer is a source of recharge, and possible contamination, of the lower aquifer,* further pollution of the upper aquifer can only increase the likelihood of pollution of the lower aquifer and jeopardize its utility as a source of potable water.

The water quality of Greene County's springs ranges from excellent (8) to severely degraded, (3, 12, 86, 89) and is affected by the quality of the surrounding surface and ground waters, the land use of the area, and the amount of protection given to springs (12).

The spring in Fantastic Caverns has been examined more than most of the other Greene County springs because it has been contaminated by industrial effluents. Concentrations of copper in Fantastic Caverns spring have consistently exceeded Missouri's maximum allowable concentration for ground waters, and have been generally increasing since monitoring began in May 1980 (31, 94, 95, 96). In addition, dye tracing studies of heavy metals pollution have demonstrated a hydrologic connection between Fantastic Caverns and Litton Industries' former waste treatment lagoon, which contained heavy metals (31, 145).

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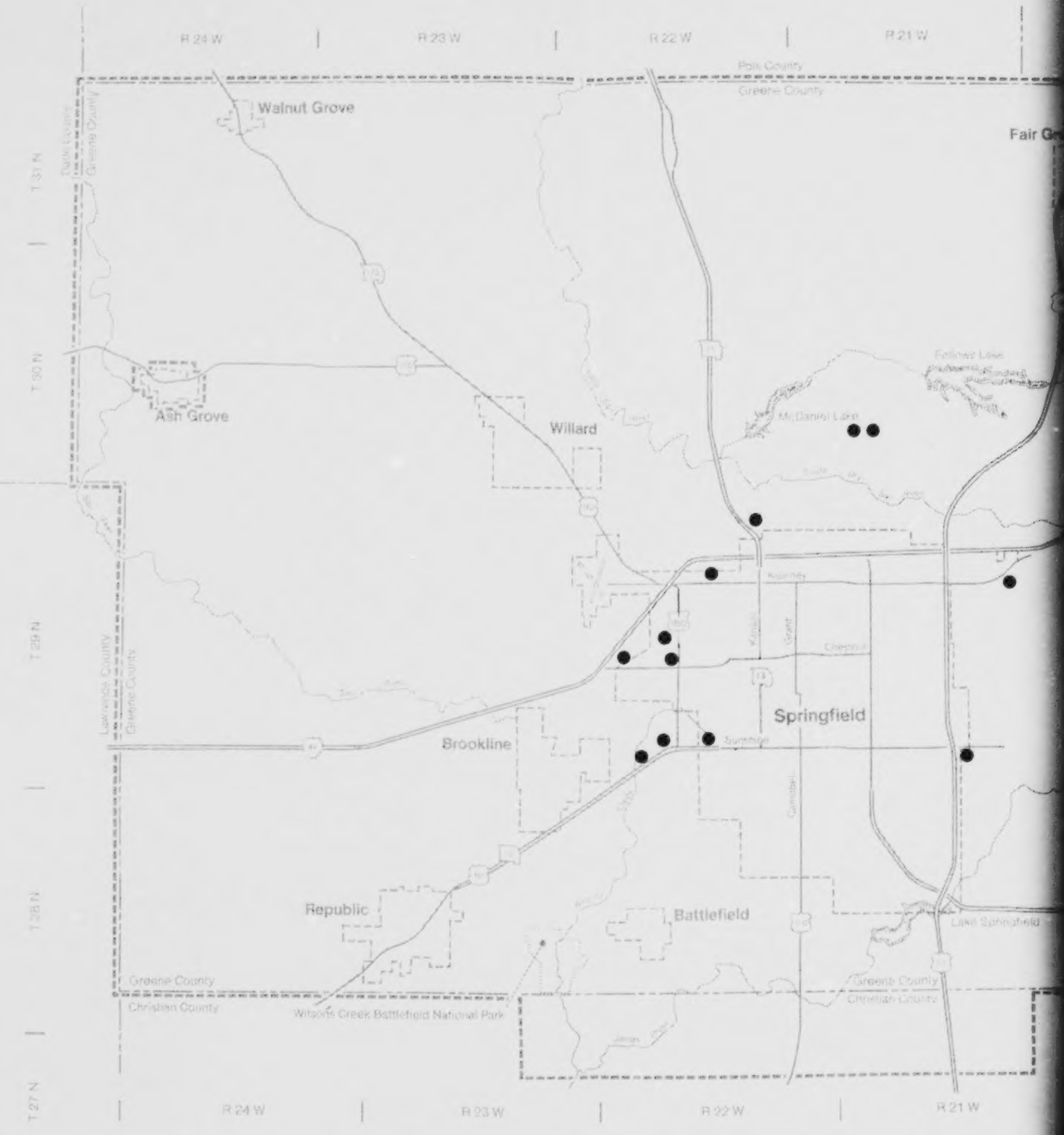
* Recharge can occur slowly through the Northview Shale, or rapidly through disruptions (wells, faults, lineaments, etc.) in the Northview Shale.

Several cases of drinking-water-borne disease in Greene County have been documented by the Health Department. The sources of contamination are difficult to trace. The symptoms of the diseases are often generalized, and the disease-causing organisms are often difficult to isolate from water (86). Cases of giardiasis, typhoid, and other illnesses borne by aquatic pathogens, along with methemoglobinemia, caused by nitrate poisoning, have been diagnosed and shown to have been contracted from private drinking water wells in Greene County (86, 88, 93).

In addition to bacterial contaminants, assorted chemicals find their way into Greene County's ground water and wells. Industries have been accused of degrading the ground water with wastes that leach through improperly constructed and sealed wastewater lagoons that are designed to be nondischarging (80). Many wells have been contaminated by gasoline leaked from underground storage tanks or from spills from wrecked tanker trucks (81, 86, 88). Figure 14 shows sites of wells in Greene County contaminated by gasoline (52). Two pipeline spills have occurred. One was from an oil pipeline where it crosses Asher Creek in Section 4, T30N, R23W. The other spill was from a fertilizer line in Section 1, T29N, R20W.

b. Sources of Pollution. The aquifers are subject to a variety of surface and subsurface sources of pollution. In a karst area, the surface and subsurface are closely interconnected with an internal drainage system. Sinkholes, open joints, faults, caves, and losing streams provide a means of introducing pollution to the ground water. Improperly cased wells, leaky pipes, and porous soils are secondary avenues of pollution. The more important sources of pollution are septic tanks, solid waste landfills, wells (particularly those which are improperly cased or sealed), improperly designed lagoons, catastrophic spills, and urban and agricultural runoff (20, 80, 86, 89).

Septic tanks are believed to be the most significant source of bacterial pollution of the aquifers in Greene County (3, 20, 86, 89). Health Department officials relate this to the poor construction and maintenance practices for septic systems and the generally unfavorable subsurface conditions for on-site wastewater treatment systems. However, septic tanks remain the major method of sewage treatment in Greene County outside of Springfield and are of signficance even within the city limits (1, 31, 86, 89, 93). Approximately 31 percent of the dwellings in Greene County are on septic tanks and about 90 percent of the county outside of Springfield, Ash Grove, and Republic are on septic systems. Many of the systems in the County are believed to be properly operating, but a system may appear to be working when it is actually discharging to the ground water (97). Older systems in particular are likely to have become clogged and to channel the septic effluent directly into the groundwater via zones of discrete recharge (89). Many of the systems near or in the city have insufficient space to operate and are failing (86). The MDNR has established minimum areas for septic system absorption fields based on soil percolation tests. However, practically any soil will pass a percolation test if tested in the dry season. Also, the percolation test by itself does not indicate whether a septic system will function properly, but only whether the soil will allow water to pass. Septic tanks do not accomplish a high degree of bacterial removal. It has been found that in some soils bacteria can travel as far as 180 feet and in fractured limestone the distance is up to 1500 feet (98). Missouri has no comprehensive statewide control of septic tank usage. Local authorities cannot regulate existing septic systems, unless a public health menace is found and so declared. Each individual septic tank is only a small producer of pollution and many persons cannot understand that individual systems can cause problems; however, the large number of septic tanks in use in the planning area must be considered. Figure 15 presents some of the areas of Greene County where septic tanks have failed (86, 93).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T 27 N
Ash Grove
Willard
Fellows Lake
McDaniel Lake
Kearney
Kansas
Grant
Chestnut
Lawrence County
Greene County
Springfield
Brookline
Sunshine
Campbell
Republic
Battlefield
Lake Springfield
Greene County
Christian County
Greene County
Christian County
Wilsons Creek Battlefield National Park
R 24 W
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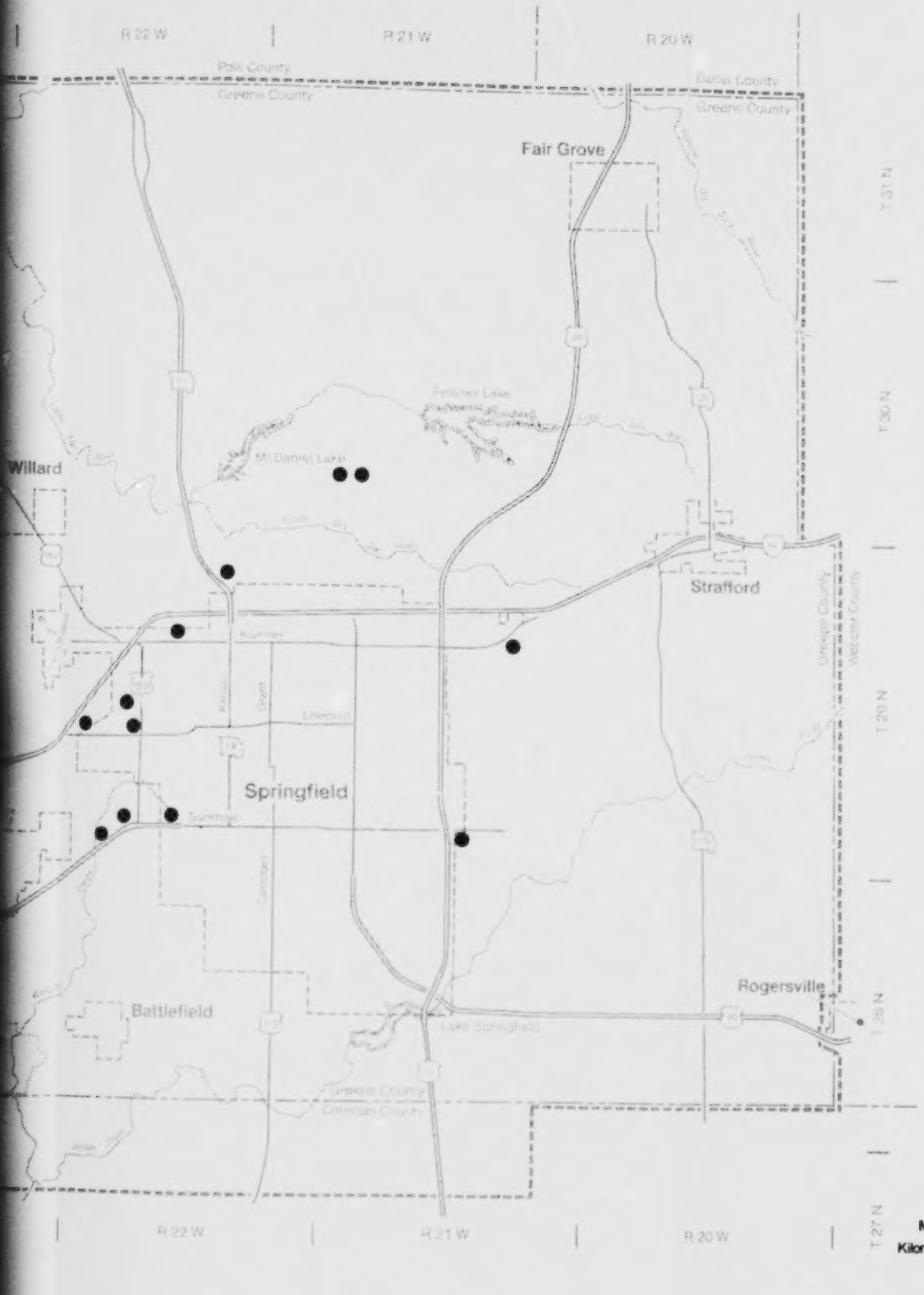
Wells Contaminated with Gasoline

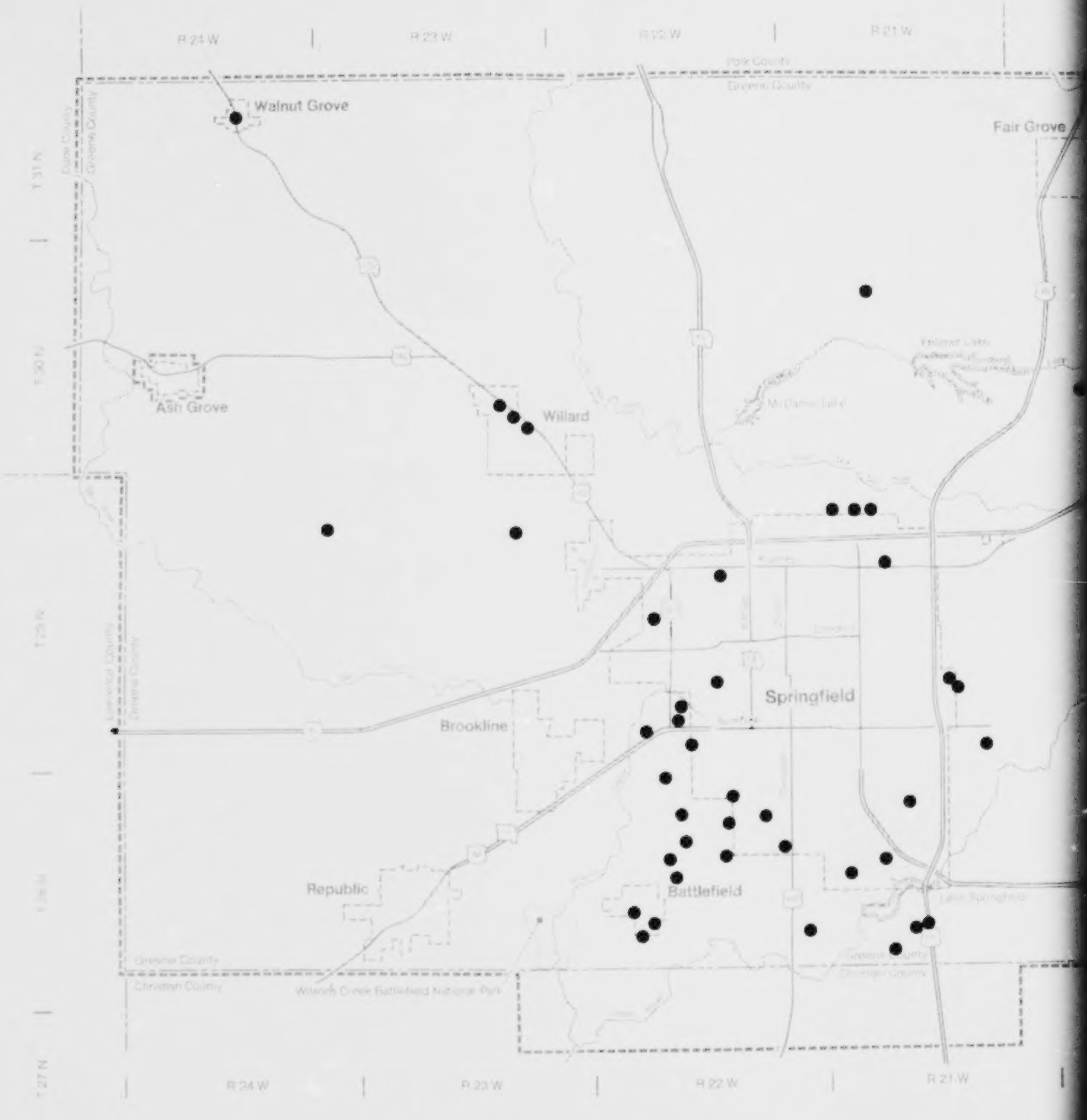
Figure 14



Legend

● Contaminated Wells

Source: (52)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Ash Grove
Willard
McDaniel Lake
Fellows Lake
Springfield
Brookline
Republic
Battlefield
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Lawrence County
Greene County
Greene County
Christian County
Wilson's Creek Battlefield National Park

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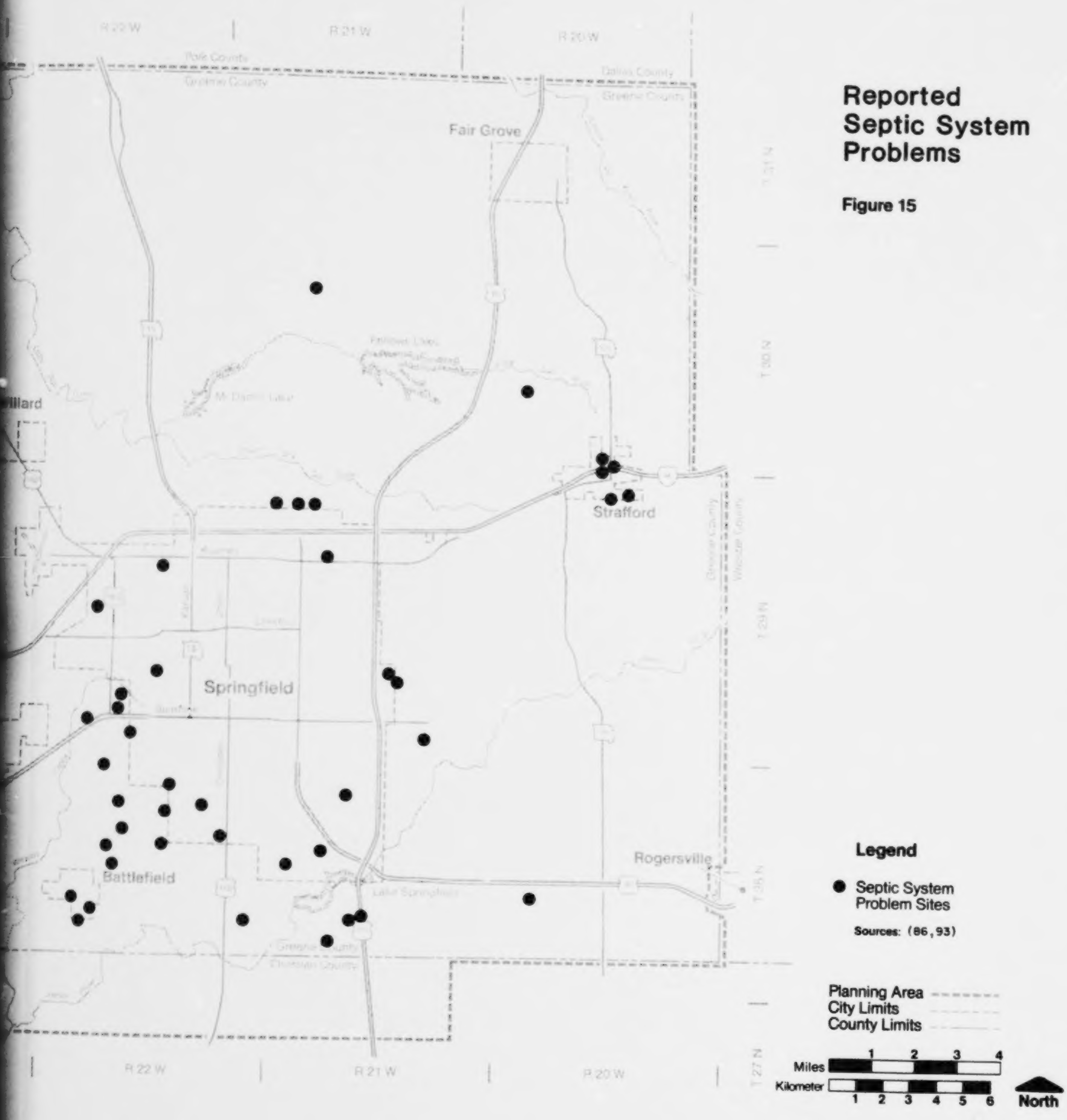
Reported Septic System Problems

Figure 15



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There are a number of abandoned solid waste landfills in Greene County that were poorly constructed and operated. Not all of the abandoned landfills have been located and few have been monitored for harmful discharges to the surface water or ground water. Two of the City's former landfills, located in the flood plains of the South Dry Sac and Little Sac River, have been shown to leach harmful substances. Many other landfills, particularly those located in flood plains, probably leach pollutants during wet weather (77).

No inventory of private wells exist in Greene County. Since no one knows where all the wells are, new wells are often drilled too close to each other or to abandoned wells. Wells that are improperly cased when drilled or improperly sealed when abandoned serve as conduits for pollutants from surface water or from contaminated aquifers to uncontaminated aquifers (3, 86, 88). This secondary contamination presents a particular danger to Springfield's drinking-water wells, which penetrate the deeper, unpolluted aquifer and have been properly cased against the upper contaminated aquifers (88). Cases of contamination have been reported in the "Swan Creek sand" (3), the uppermost layer of the deep aquifer. The Missouri Geological Survey is recommending that wells for domestic use in the Springfield area be properly cased below the "Swan Creek" which ranges in depth from about 350 to 400 feet (98, 99).

Migration of pollutants to ground water from improperly sealed industrial wastewater lagoons has not been quantified but is known to exist (80, 89). Collapsed municipal lagoons have been shown to pollute groundwater in the area (52).

The 1968 collapse of the southeast waste treatment lagoon in the City of Republic catalyzed added concern about such geologic hazards. In a 24-hour period, approximately 4 MG of sewage drained into a sinkhole that opened up in the lagoon floor; additional drainage occurred two days later when a second sinkhole fell in. The failure occurred because the lagoon was constructed in pervious residual soils and partly over sinkholes that had been filled during construction. Several wells and springs in the Shuyler Creek watershed were contaminated by sewage released after the lagoon collapsed (100, 101). Careful study should also be undertaken before land application systems are installed as a means of disposing of sewage wastes in a karst region, such as the planning area, where limited soil thickness and permeable "terra rosa" soils (residual from the solution of limestone) occur.

Urban and agricultural runoff is a significant source of ground water pollution in areas such as Greene County, where numerous surface-to-ground water connections exist. These connections permit the polluted surface flows to be channeled directly to the ground water, bypassing the normal filtering process. Sinkholes in particular serve as a natural point for collection and transport of surface runoff to the subsurface. This is especially troublesome near Springfield, where extensive development has occurred near or on sinkholes, thus increasing the pollutant load to the subsurface and the threat of ground water contamination (38, 89).

3. Water Supply Quality

Protecting the quality of existing and potential water supply sources is extremely important in Greene County. Because the area is situated on a major drainage divide, surface water supplies are limited in quantity and capacity to assimilate pollutants. Ground water resources are also limited and very vulnerable to pollution because of the karst topography with close and complex interconnection of surface and ground water.

a. Drinking Water Regulations. In accordance with the Federal Safe Drinking Water Act of 1974 and the Missouri Safe Drinking Water Act of 1978, the Missouri Department of Natural Resources has issued Missouri Public Drinking Water Regulations (102). The regulations specify maximum contaminant levels (mcl's) and monitoring requirements for microbiological, physical, inorganic and organic chemical, and radionuclide contaminants. In addition to mcl's based on health factors, secondary mcl's for contaminants that may cause aesthetic or other non-health problems are specified. Examples of health based mcl's include: coliform bacteria; turbidity; nitrate, heavy metals such as cadmium, lead, and mercury; certain pesticides and radionuclides; and a class of volatile organic chemicals known as trihalomethanes (THM's). Examples of secondary mcl's are color, iron, odor, and sulfate.

Other contaminants could be regulated in the future if found to be warranted by studies on occurrence, health significance, and control technology. Also, parameters that are not routinely monitored and regulated in public water supplies may be a problem in a specific situation.

b. Water Supply Concerns. Growth and development and related wastewater management in Greene County may impact water supplies in many ways. Both surface and ground water contamination could cause serious problems.

Ground water concerns are magnified by the vulnerability of the aquifers in Greene County and the difficulties in detecting or reversing pollution effects. Most ground water supplies in Greene County receive little or no treatment. The larger supplies are protected by properly constructed deep wells, but individual and other private wells are often shallow, inadequately cased and sealed, and not monitored for quality. Increasing development and the soils, geology and other problems causing on-site wastewater treatment systems to malfunction, result in surface and ground water degradation in many areas.

There is pressure for residential and industrial growth within the Springfield water supply watersheds, and potential surface water pollution from associated domestic and industrial discharges and nonpoint sources is a major concern. Nonpoint pollutants in stormwater runoff include microorganisms, sediments, heavy metals, pesticides, nutrients, and oxygen-demanding materials. Both rural and urban land uses contribute significant amounts of nonpoint pollution.

Rural sources of pollution include cultivated land, livestock operations, and rural roads. Erosion of cultivated lands, pasture, and rural roads produces large quantities of sediment. Chemicals applied for agricultural lands may be absorbed and transported on soil particles to surface waters and some may also reach the ground water. Livestock operations result in microbiological contamination and in soil erosion from overgrazing.

Urban sources of pollution include wastewater disposal, motor vehicles, construction activities, and various land uses and associated activities. Septic tank systems and package treatment plants often cause serious water quality problems and leaking sewers may also pose a threat. Roads contribute large volumes of sediment and motor vehicles are implicated as a major source of heavy metals. In addition to heavy metals, sand, and silt, street runoff has been found to include organic matter, nutrients, coliform bacteria, and pesticides. Sediment is the chief contaminant from construction activities. The type and intensity of development is the most important consideration concerning nonpoint pollution loads. As runoff in an urban area increases from development, more contaminants are transported to surface waters. A much higher proportion of rainfall runs off commercial and industrial land than off residential land.

Springfield City Utilities examines zoning changes and NPDES permit applications which may affect its watersheds. When there is significant water supply concern, this is voiced to appropriate agencies, often, the Greene County Zoning and Planning Commission.

In response to taste and odor problems experienced during the late summer of 1982 and attributed to algae growth in McDaniel Lake, Springfield City Utilities initiated a study of the McDaniel and Fellows lakes watersheds. The study is planned to gather information on water quality, nutrient loading, and biological populations in the lakes and tributaries. Using this data, it is hoped that predictive models for evaluating water quality can be developed, including the water quality changes from watershed development.

c. Specific Quality Parameters. MDNR chemical water quality analyses of the water supplies serving Battlefield, Bois D' Arc, Republic, Springfield, Strafford, Walnut Grove, and Willard show no problems in compliance with Public Drinking Water Regulations for toxic chemicals. Recent special testing of Republic's well water, as part of a survey of 84 water supplies around Missouri, revealed trace amounts of trichloroethylene (TCE) and other compounds (103). There is presently no drinking water standard for TCE, a widely used solvent, and the amounts found pose no immediate health risk although there is precautionary concern about possible long-term effects. Results of follow-up investigations by MDNR are not yet available. In addition to dissolved toxics, other pollutants may have significant impacts on Greene County water supplies. These include nutrients (phosphates and nitrates), organics contributing to THM formation, sediment, and microbiological contaminants.

Excessive sediments can make water treatment more difficult and increase chemical costs. Sediments also cause siltation, reduced capacity, and vegetation problems in storage reservoirs. Excessive microbiological contaminants can cause disease outbreak.

Excess nitrates (greater than 10 mg/l) in drinking water may cause methemoglobinemia, a serious and sometimes fatal poisoning in infants. Nitrate, or other nitrogen forms that are converted to nitrate, are found in fertilizers and sewage.

Nutrients may also cause problems by increasing aquatic plant growth. This may in turn cause taste and odor or other nuisance conditions for water supplies, plus increased treatment costs for control.

Phosphate is often the key nutrient in aquatic plant growth and lakes are particularly affected by nutrient levels. Nutrient enrichment increases productivity and accelerates the natural aging processes of lakes. Phosphate is found in fertilizers and sewage, including contributions from phosphate detergents. Preliminary estimates of phosphorus loading and hydraulic residence times characterize McDaniel Lake as eutrophic (nutrient enriched and high in productivity) to mesotrophic. Mesotrophic is a condition between eutrophic and oligotrophic (very low in nutrients). Fellows Lake is characterized as oligotrophic to mesotrophic. Livestock operations are noted as the likely cause of high phosphorus concentrations observed in a tributary entering the Little Sac River between McDaniel and Fellows lakes (104).

THMs are a group of compounds commonly formed during potable water disinfection with chlorine. THMs are not normally found in untreated surface or ground waters, but occur in virtually all treated supplies using free* chlorine disinfection. The chlorine reacts with various organic compounds in the water known as THMs precursors. The precursors are primary naturally occurring organic compounds, known as humic and fulvic acids, formed from the decay of plant material.

THMS are formed when three halogen atoms (usually chlorine or bromine) react into a methane molecule (CH_4). The resulting compounds are chloroform ($CHCl_3$), bromodichloromethane ($CHB4Cl_2$), chlorodibromomethane ($CHClBr_2$) and bromoform ($CHBr_3$). Measurement of all four is expressed as total THM (TTHM). In recent years the USEPA established a mcl of 0.10 mg/l for TTHM and MDNR issued compatible regulations for control and monitoring of TTHM in drinking water supplies serving 25 or more residents. The TTHM standard is based upon evidence of cancer-related health risk.

Springfield City Utilities has conducted quarterly monitoring for TTHM since the fourth quarter of 1980. For the nine quarters through the end of 1982, TTHM in the distribution system averaged 0.045 mg/l (ranging from 0.024 to 0.065 mg/l), well within the 0.10 mg/l standard. Samples associated with water produced by Springfield's Fulbright Plant averaged 0.044 mg/l. The Blackman Plant was operating during three of the nine quarterly monitoring periods and TTHM in water produced by this plant averaged 0.048 mg/l (ranging from 0.042 to 0.052 mg/l). This compares to an average of 0.043 mg/l TTHM for Fulbright Plant water during the same three quarters. Traces of chloroform but no quantifiable amounts of TTHM were detected in the raw water sources (105).

Present TTHM levels at Springfield are not a problem, but there is concern that increased watershed development and potential wastewater discharges might cause future problems. Although natural humic and fulvic materials are generally the most important precursors, humic or humic-like materials in wastewaters and other precursors in water may also be signficiant. Much research is needed and being conducted on the very complex subject of the occurrence and significance of THMs and other carbon-halogen compounds formed during disinfection of water and wastewater (106, 107).

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* Chlorine residual may also be in combined forms which produce little or no THM. For example, chlorine reacts with ammonia to form the combined chlorine residual compounds known as chloramines.

One laboratory study of filtered secondary wastewater effluent subjected to high free chlorine dosage (20 mg/l for 100 hours) found that 0.030 mg of $CHCl_3$ were formed per mg of total organic carbon (TOC). This compares to 0.049 to 0.085 mg $CHCl_3$ per mg of TOC from humic and fulvic acids (108). These results for secondary effluent are comparable to another study that found TTHM production from secondary effluent, subjected to free chlorine (20 and 40 mg/l dosage for 24 hours), to be about 4 micromoles per liter (109). (This converts to about 0.5 mg/l as $CHCl_3$.)

Algae are also indicated to be potentially significant THM precursors. One study found that aqueous chlorination of chlorophyll yields chloroform and that algae as well as humic and fulvic acids may be THM precursors (106). Results from another conclude that the diverse organic compounds found in algae and related extracellular products produce THM concentrations that are comparable to yields from humic and fulvic acids (109). Another concludes that both algae and heterotrophic organisms (those requiring organic compounds as nutrients as characteristic of animals) are involved in the production of THM precursors (110). Thus factors, such as nutrient enrichment, that increase aquatic productivity may also increase THM precursors.

To keep the subject of THMs and chlorinated organics in perspective, it is important to realize these by-products of water and wastewater chlorination are present in very small quantities, that only a portion of such compounds can be identified with current analytical techniques, and many questions and much debate remain as to health significance. Current standards weigh present knowledge but can be expected to change and be supplemented in the future. Using a high quality source of water and protecting water supply watersheds still play a very important role in drinking water quality. Meeting current standards and avoiding health risk from materials not covered by current standards are not assured by conventional water treatment and monitoring systems alone.

4. Aquatic Ecology

a. Stream character.

1) Ozark Streams. Ozark streams, which include the White River basin streams in the planning area and the headwaters of the Sac, Little Sac, and Pomme de Terre rivers, generally flow through a complex system of rugged hills, but in the planning area, where there is a major stream divide, extensive areas of relatively level topography remain. The streams themselves typically consist of a series of short pools and well-defined riffles. Chert, washed down from the surrounding slopes, is the most abundant bottom type. Rubble and bedrock are not uncommon, and limestone boulders that have fallen away during bluff formation partly block the channel in places. Ozark streams are the clearest in the state because much of the water that enters them is first filtered through unconsolidated deposits of chert.

2) Prairie Streams. Prairie streams are most evident along the western edge of Greene County. While the rolling plains in this area are nearly as high as parts of the adjacent Ozark region, the Sac and Little Sac rivers occupy valleys that are flatter and slope more gradually than those found in the southern part of the planning area. Generally, the bottom types are in a transition from chert to mixture of chert, silt, and gravel. The water also tends to be more turbid due to erosion of the clay soils disturbed by agricultural practices.

b. Fish fauna. Native fish are distributed according to stream systems. Often a species that is widespread and abundant in one stream system is absent from an adjacent stream basin, although the habitats are similar. While streams may be only a few miles apart by an overland route, they might be hundreds or thousands of river-miles apart. Thus, a fish in the Sac River in Greene County would have to swim over 1,500 miles to enter the James River in the same county. As the Ozark dome erodes over geologic time, streams extend their drainages headward into the areas they drain. In doing so they sometimes "capture" streams of other systems, thus diverting their flow and all of the fish that are present from one system to another. As a result of these events, species become established in two separate stream systems. Over the millenia, separate populations may slowly evolve into subspecies or separate species. The common occurrence of different but closely related fish lends evidence that this has happened many times. Thus, the bleeding shiner and Missouri saddled darter, two fish in the Sac River and other northern Ozark streams, are replaced in the James River by two closely related species, the dusky stripe shiner and Arkansas saddled darter (111). While land still impedes the interchange of many species, man has altered the distribution of the local fish fauna by introducing non-native fish (carp) or species found outside the area's stream systems (Northern pike).

Habitat types in the planning area's streams can be roughly divided into pools and swift-flowing riffles. In general, the species of a single group such as a genus or family occupy similar habitats. For example, nearly all members of the sunfish family (bass, bluegill, and crappie) prefer quiet water. Most of the man-made reservoirs and ponds are stocked with native fish that inhabit quieter sections of streams. In contrast most darters prefer flowing water and many inhabit the swift-flowing riffles.

Fish species known to occupy the upper reaches of the James, Sac and Pomme de Terre river drainage basins are listed in Appendix C, Table C-1. Habitat preference and abundance information for each species is also included to illustrate the importance of each habitat type.

Fish kills were a regular event in the James River below the confluence of Wilsons Creek prior to the construction of Springfield's upgraded advanced secondary treatment plant located on Wilsons Creek. Other fish kills that have occurred in the planning area include the following (112, 113, 114, 115):

Location and Water Affected	Date	Cause	Damage
Springfield, MO; Little Sac River	11/30/78	Landfill seepage	Not available
Springfield, MO; Unnamed tributary to James River	12/20/78	Rupture of liquid nitrogen fertilizer pipeline	Killed an undetermined number of fish in a 1.3-kilometer (0.8-mile) section of stream
Asher Creek	1979	Not available	Not available
McDaniel Lake	4/23/80	Post-spawning mortality and spring temperature inversion	Killed 1000-2000 shad

Several recent fish kills on the Little Sac River (116, 117) have been caused by the inadequately treated effluent from the overloaded Springfield Northwest WWTP. More than 4,000 fish were estimated to have been killed in the early July 1982 incident, due to low levels of dissolved oxygen coupled with high levels of ammonia nitrogen.

c. Benthos. The most extensive studies concerning benthic macroinvertebrates have been made during water quality evaluations, which included the James River basin (118, 119). Benthic organisms were investigated due to their ability to indicate the water quality of a stream by the types and relative numbers present at particular locations. As a result of their limited mobility and their location in the stream bottom, benthic communities are adversely affected by poor water quality. When the water quality is poor, certain species are eliminated and others may increase to greater numbers than would normally occur.

In a 1964-65 study, the majority of the types of benthic fauna collected in the James River upstream from Lake Springfield were members of clean-water groups (range from 46-62 percent). The benthos found along the upper reaches of the James River indicates that the main branch of the river was unaffected by pollution from Springfield (118). A more recent study (1978) indicates biologically healthy conditions in the James above and below Lake Springfield and in Wilsons Creek (see Appendix C, Table C-2).

Pierson Creek drains an area about three miles east of Springfield which is heavily used for dairy farming. Over half (56 percent) of the benthic fauna sampled were clean-water types, which indicated good water quality (118).

Sequiota Creek contained a fauna indicating a disturbed situation. The preponderance of pollution-tolerant organisms and past fish kills indicated occasional pollution problems on Sequiota Creek (118).

Before the upgrading of Springfield's Southwest Sewage Treatment Plant in 1977, Wilsons Creek was essentially a conduit for improperly treated sewage. Thus, many life forms, such as worms (Oligochaeta), leeches (Hirudinea), snails (Physa sp.) and midge larvae (Chironomidae), inhabiting Wilsons Creek and Rader Spring were extremely tolerant of organic pollution. The combined effects of poor-quality stormwater and treatment plant deposits on the bottom of Wilsons Creek often devastated the aquatic fauna in the James River. The resulting low oxygen concentration in the water suffocated fish and supported a spare benthic fauna with only 23 percent clean-water types. Benthos samples taken in Wilsons Creek since the improvements to Springfield's Southwest Plant indicate that conditions have improved (119). The creek is now capable of supporting a more diverse benthic community (see Appendix C, Table C-2) and fish again inhabit the creek (120). However, the diversity in Wilsons Creek is still low when compared to other streams sampled in the planning area, most likely due to the pollution from urban runoff and occasional release of storm water overflows from the treatment plant during heavy rainfall. These two factors may preclude the possibility of Wilsons Creek once again becoming a high quality Ozark stream. Fish kills in the James River previously associated with the gross pollution of Wilsons Creek should no longer occur. No benthos samples have been taken immediately below the confluence of the two streams, but the water quality data from the study of 1964-66 showed a gradual improvement in the composition of the benthic community in the James River about 14 miles downstream from Wilsons Creek, where 48 percent of the benthos was of clean-water types. Improved conditions were attributed to the natural stream purification process and the inflow of good-quality water from Finley Creek. The benthos above this stretch of the James River has improved since the completion of the improved waste treatment plant.

The only known study concerning benthos in the northern part of the planning area, which includes the Sac, Little Sac, and Pomme de Terre River basins, is the 1975-76 Osage River Basin Survey, which is not yet published by the Missouri Department of Conservation (112). Aside from the effluent from Springfield's Northwest Treatment Plant into the South Dry Sac River--a tributary of the Little Sac--the water quality of these streams is not impacted by major urban influences. Much of Springfield's water supply comes from these watersheds, an indication of the area's water quality. Considering these factors, the northern-flowing streams (other than the stretch of the South Dry Sac and Little Sac rivers impacted by the Springfield Northwest Treatment Plant) probably support diverse benthic communities, with over half the species from clean-water groups.

d. Lakes and Ponds. The major impoundments in the study area are McDaniel Lake, Fellows Lake, and Lake Springfield. In addition to the natural fish fauna occurring above these impoundments such as members of the sunfish family, these lakes are stocked with additional species. Fish stocking programs by the Missouri Department of Conservation have been limited in the planning area to largemouth bass and bluegill in private ponds, and threadfin shad in Lake Springfield (112). No information is available on lake and pond benthos in Greene County.

e. Springs. Certain aquatic species are restricted to the cool Ozark spring waters (12°-16°C) and are ususally not found in Missouri outside this region.

1) Flora. The only spring in Greene County that has been botanized is Cave Spring, near Pearl. It flows about 200 feet, then enters Asher Creek. The only higher plant found on the spring branch is watercress. Aquatic mosses (*Fissidens* and *Fontinalis*) are also found with watercress in an unnamed spring about one-eighth mile from Cave Spring on Asher Creek. A list of plants that are characteristic of springs and their branches is shown in Appendix C, Table C-3.

2) Fauna. The fish fauna of springs and subterranean waters is quite limited. The two most characteristic species in springs and spring-fed streams are the mottled and banded sculpin. Rainbow trout, an introduced game fish, has been widely stocked in spring branches and cool spring-fed streams.

Five species of salamanders inhabit spring and underground streams in the area; they include the Ozark hellbender, long-tailed salamander, cave salamander, gray-bellied salamander, and grotto salamander. The only frog that is common in springs and caves is the pickerel frog.

The benthos occurring in Missouri's springs has received little study. Some of the invertebrates found in cold springs in the southwestern Missouri Ozarks are shown in Appendix C Table C-4. Some of these species are also known from cave streams.

D. TERRESTRIAL ECOLOGY

1. Regional Affinities

a. Ozark Plateau. The eastern two-thirds of Greene and Christian counties are within the Ozark plateau. This region possesses the most diversified flora, including the greatest number of species, in the entire state. Most of Missouri's endemic plant species occur in the Ozark region. The wealth and diversity of the flora can be attributed to the present topography, drainage, climate and surface geology of the region. Generally, the climax flora of the Ozark region is a mesophytic (medium moisture conditions) forest. The original forest cover of the Ozark area was dominated by an oak-hickory association, interspersed with short-leafed pine. Most of the original timber has been logged or burned, so that large upland forest areas consist of less valuable second-growth oaks. The forest with its associated herbs belongs to the Carolina flora; it is intermediate between the austral (southern) and boreal (northern) phases, with a slight predominance of southern species. The herbaceous plants of general distribution on the uplands are usually species that range from the eastern Appalachian plateau to the western prairies (121).

The wildlife species occurring in the Ozarks are primarily forest-dwellers. Because of its central location in the United States, the native fauna of the Ozarks has origins in three geographic elements (122, 123). Geographic affinities and examples of wildlife species from each element are: (1) Eastern-Southeastern least shrew, Carolina chickadee, and Western cottonmouth; (2) Southern-Southwestern opossum, roadrunner, collared lizard, and Eastern narrow-mouthed toad; (3) Northern-Northwestern beaver, marsh hawk, Northern water snake and wood frog. The geographic origins of a fourth rather widespread faunal element are somewhat obscure and cannot be included in any of the above categories. Examples in this assemblage include: raccoon, robin, Eastern garter snake, and tiger salamander.

b. Osage Plains. The western third of the planning area is in the Osage plains or unglaciated prairie. The Osage plains merges irregularly and indefinitely into the western border of the Ozark plateau. Within this broad transition zone, Ozark flora is still dominant on broken rocky ground along streams, while the prairie and plains flora occupies the more level and open sections of the uplands. More than in any other part of the state, the prairie flora has been better preserved in this section due to the maintenance of large tracts used for grazing and hay production (121).

The Osage plains wildlife originates from a fauna associated with the prairies; thus, the geographic affinities are with those species from the West and Southwest. They include such species as the black-tailed jackrabbit, greater prairie chicken, bull snake, and Woodhouse's toad.

The geographic origins of both the Ozark plateau and Osage plains elements indicate the general direction from which each major faunal unit reached Greene County. However, because of the diversified habitats found in the planning area, particularly where the prairie penetrates the forests or where land use practices have opened the woodland cover, much of the wildlife that once occurred in either the Ozark plateau or Osage plains has dispersed into both regions.

2. Plant Associations

Ozark and prairie plant associations are found in the planning area and are summarized below. Additional details on the Ozark plant associations are given in Appendix D - Section 1 (124, 125, 126).

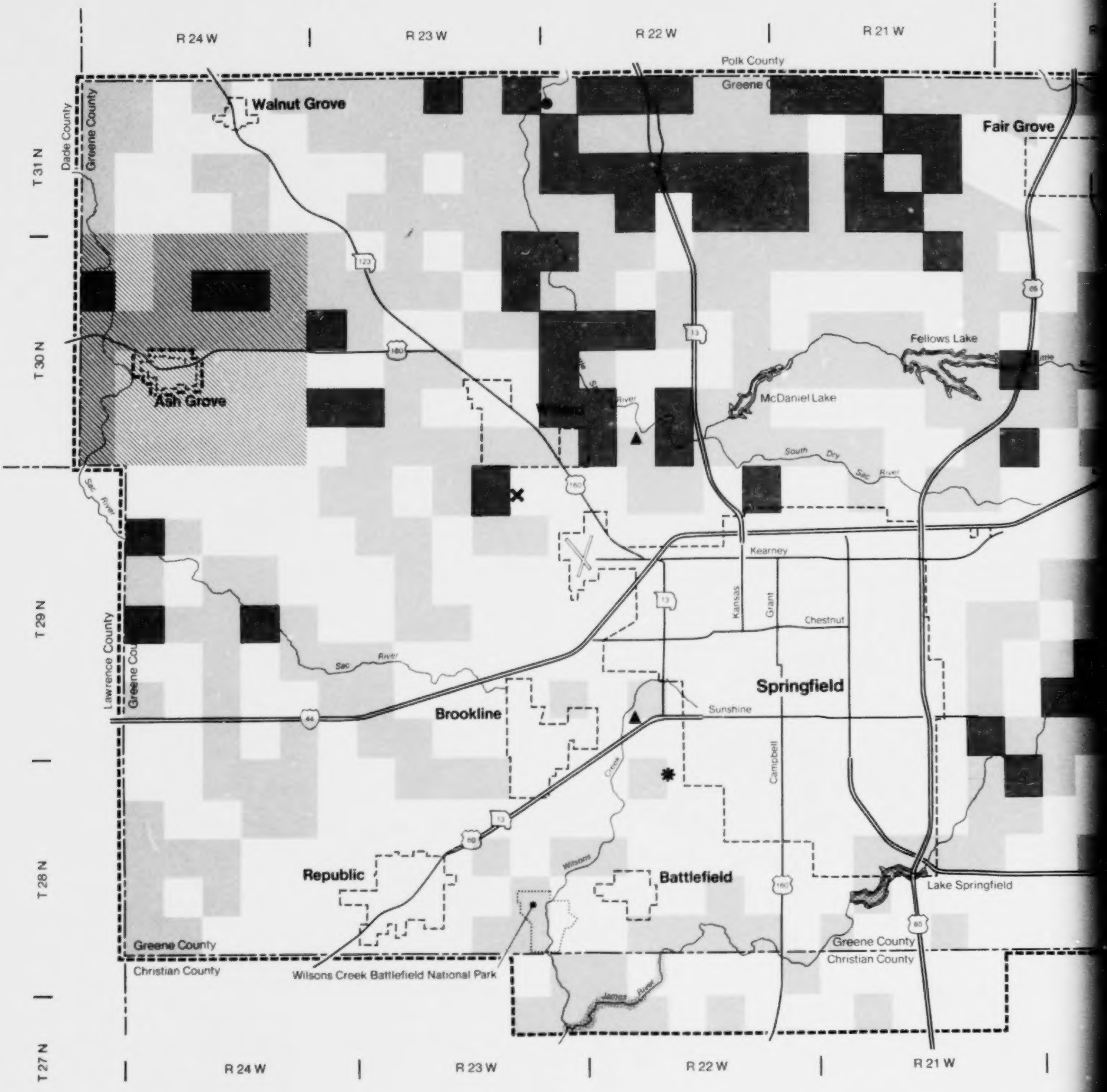
a. Ozark Plant Associations. The various plant associations in the Ozarks have developed under the influence of several physiographic and ecological phenomena: (1) stages in floodplain formation; (2) ridge tops and plateau areas; (3) ravines and upper drainage heads of the tributaries in acid soil areas; and (4) stages of prior vegetative cover over eroded limestone bluffs or open glades. Many plant associations, therefore, depend on the type of rock where they originally developed. Certain species have adapted to the acid soils derived from sandstone, cherts, and granitic rocks, while other plants are associated with the alkaline soils originating from limestones and dolomites. The wooded portions of the planning area are indicated in Figure 16.

1) Sugar Maple-Bitternut Hickory Association. This association is the climax stage of floodplain flora, and developmental stages correlate with the development of the stream. The first stage occurs when the stream is small with a rocky bed and many gravel deposits. Dominant trees are Ward's willow and sycamore. As the soils become richer through the addition of humus layers mixed with sandy alluvium, a greater number of shade-tolerant trees and shrubs appear, and a second developmental stage of buttonbush, blackwillow, silver

maple, green ash, and elm occurs. The final developmental stage is dominated by sugar maple and bitternut hickory; the pawpaw, American hornbeam, flowering dogwood, buckbrush, coral berry, spicebush, and greenbriar are often abundant understory species. Sycamore, elm, and ash also persist as very common species in the final stage of floodplain flora development.

2) Sugar Maple-White Oak Association. The first stage of this association occurs on rocky limestone glades giving rise to alkaline soils. The flora is dominated by herbaceous prairie species. Where glades and eroded limestone slopes face west or south, the dry sun and wind conditions favor herbaceous rather than forest coverage and the herbaceous stage may last indefinitely. On slopes facing east and north, more moisture and protection from prevailing winds allow faster soil building and a more rapid succession to the climax sugar maple - white oak association. Following the pioneer herbaceous flora, woody plants such as red cedar, fragrant sumac, and persimmon occur. As rock disintegrates and soil increases, shrubs of the chittimwood - black haw stage follow, then other shrubs and trees cover the glade shading out the red cedar. Winged elm - Indian cherry and chinquapin oak - white ash stages often follow. As more soil is formed, sugar maple makes its appearance and, finally with white oak, attains dominance. Other common species in this climax association are northern red oak, linden, and butternut. The dominant understory consists of flowering dogwood and American hornbeam and a lower story may consist of spicebush and bladdernut. In its final development stages, the sugar maple-white oak assocation closely approaches the composition of the floodplain climax association of sugar maple-bitternut hickory.

3) Oak-Hickory Association. This is the common and prevailing association over most of the planning area's ridges, uplands, and upperhill slopes. It develops on drier and more acidic soils, and is probably the most complex association in the region. It originates from a prairie association on acid soils from sandstone, chert, or granite. Woody plants such as sassafras, winged sumac, fragrant sumac, and persimmon invade the prairie flora and comprise the sassafras-winged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Polk County
Greene County
Walnut Grove
Fair Grove
Dade County
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123
160
13
65
Ash Grove
Willard
Little Sac River
Fellows Lake
McDaniel Lake
South Dry Sac River
Sac River
Kearney
Kansas
Grant
Chestnut
Springfield
Sunshine
Campbell
44
Brookline
Lawrence County
Greene County
Sac River
60
Republic
Battlefield
Wilsons Creek
Lake Springfield
Greene County
Christian County
Greene County
Christian County
Wilsons Creek Battlefield National Park
James River
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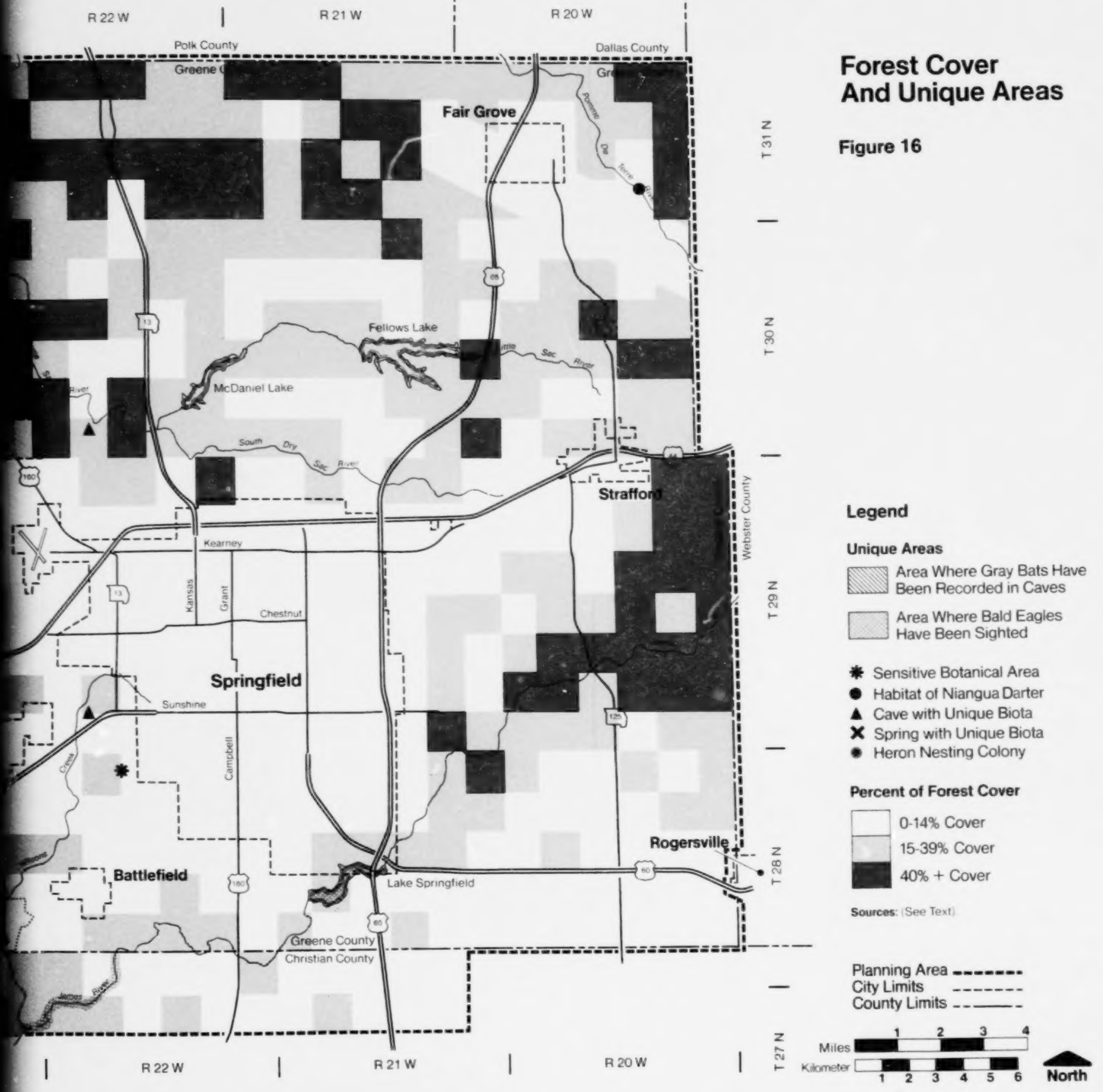
Forest Cover And Unique Areas

Figure 16



sumac stage. In the next stage, blackjack oak and post oak penetrate the area followed by the black oak-black hickory stage of succession. The black oak grow rapidly, and shade and dominate the light-demanding blackjack and post oaks. Dominant understory shrubs consists of low-bush huckleberry and deerberry or farkleberry. Black hickory is more common on ridges or plateau tops and on south and west slopes.

4) White Oak-Red Maple Association. This association commonly develops from drainages in acid soils such as the heads of streams and upper slopes of hills and ravines. Development is initiated by pioneer trees, that occupy a slight draw eroded by rainwater. The trees may include flowering dogwood, blackgum, witch hazel, sassafras, and lesser numbers of red maple. As the drainage becomes more deeply dissected, red maple and mockernut hickory dominate, and smooth sumac, winged elm, serviceberry and species of the preceding stage are also found. The diversity of the forest increases as the ravine deepens and more soil accumulates, and white, scarlet, and black oaks are found. Northern red oaks and bitternut hickories may also occur. In the final stage, white oak and red maple dominate. Blackgum and mockernut hickory are the tallest trees of the association, while flowering dogwood, sassafras, and serviceberry form the understory. As the ravine or valley is enlarged, the flora from the lower slopes and valley penetrates the richer slopes and ravine bottom of the new drainage with such species as pawpaw, American hornbeam, spicebush, redbud, chinquapin oak, butternut, shagbark hickory, and mulberry. Flora of ridge tops and upper slopes may also overlap that of the ravine. Very diversified flora may thus be encountered over the course of a ravine.

b. Prairie Plant Associations. According to United States Land Survey records, about one-third of the planning area was originally native prairie (128). This prairie was likely a part of the prairie parkland province that covered an extensive area from Illinois to the Gulf Coast with alternate areas of prairie and deciduous forest. The former distribution of natural prairie in Greene and Christian counties illustrates such a prairie-forest mosaic, resulting chiefly from local soil conditions and slope exposure. Prairie flora occupied thin soils

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on top of limestone hills and areas where frequent fires removed the woody plants, while trees predominantly grew near streams and on north-facing slopes.

1) Prairie. Most of the area's true prairie has been destroyed by plowing. Next to the plow, overgrazing and subsequent reseeding with introduced species have been the chief causes of prairie degeneration (129). In the planning area, vestiges of native prairie remain in areas which are generally unsuited for cultivation. Prairie species are still found on rangeland, but are seldom retained in their original diversity. Prairies are also found on small tracts, such as fenced rights-of-way of railroads, that have been protected to a large extent from extreme disturbances. Plants characteristic of the Osage plains in general include: panic grasses (Panicum scoparium, P. malacophyllum), tumble grass, silver beard grass, spike rush (Eleocharis lanceolata), prairie anemone, meadow beauty, marsh pink (Sabatia campestris), and dwarf dandelion (Krigha occidentalis) (121).

Some of the more common prairie grasses found in the planning area are big and little bluestem, switch grass, Indian grass, prairie cord grass, and sideoats grama. Herbaceous broad-leafed plants (forbs) are well represented by the composite family and the legume family. Common composites include sunflowers, rosinweeds, blazing star, goldenrods, asters, and coneflowers. Common legumes include leadplant, false indigo, prairie clovers, and scurf-pea (130).

2) Pasture. In some areas where the prairie has been only partially altered by the range-cattle industry, both introduced and native prairie grass and forb species coexist in pastures. These areas include species such as big and little bluestem, prairie grass (Panicum lanugenosum), prairie foxtail, Canada blue grass, Kentucky blue grass, Indian grass, timothy, broom sedge, switch grass, redtop, prairie dropseed, crested hair grass, orchard grass, six-week fescue, lespedeza, and a variety of clover (129). Much of the native prairie in the planning area has been removed or drastically changed, however, by the revitalized cattle industry. Land is cleared by bulldozer or by aerial

applications of herbicides, and monotypic crops of winter hardy fescue are planted. Critics of this practice maintain that the region is being converted to a "fescue desert" (128).

3) Old field. Some of the formerly cultivated or grazed lands have been abandoned. During the first few years after abandonment the area is termed "old field." These old fields are in the beginning stages of secondary succession, which takes place following the destruction of part or all of the vegetation in an area. Grasses and forbs are the initial plants to occupy an old field and include ragweed, aster, partridge pea, poverty grass, broomsedge, trefoil, daisy fleabane, yarrow, goldenrod, Kentucky blue grass and cinquefoil. The first woody plants to invade an old field are dominated by red cedar, smooth sumac, persimmon, honey locust, sassafras, rasberry, and coral berry (131, 132).

3. Wildlife

Just as plant associations are influenced by a wide variety of environmental parameters, so are the wildlife species that inhabit these associations. Within the geographic range of a given species there are certain types of natural settings or habitats to which that species is suited. These habitats result from the interaction of such factors as climate, soil, topography, plant and animal life, and land use. For each species, certain physical and behavioral features have evolved, enabling the animal to exploit its habitat (133). Among the most important are features related to feeding. The feeding relationships within an ecosystem, often referred to collectively as the "food web," control the transfer of energy and inorganic nutrients through the system. Food webs are outlined for each of the major types of biotic communities in the planning area in Figure 17.

Mammals, birds, reptiles, and amphibians found in the planning area are discussed below. Appendix D - Tables D-2, D-3, D-4, and D-5 list the species present in each of these categories.

Species of wildlife are best discussed in terms of general types of habitat such as upland forest, bottomland or riparian forest, prairie, old field, and urban land. However, the species of wildlife present depend upon which associes or stages are present. For example, the early sugar maple-bitternut hickory associes do not have trees that produce mast (nuts and acorns); hence, squirrels or other species which depend on this food source will not be present.*

a. Upland Forest. Upland forest habitat occurs on ridge tops and summits of Ozark hills where dry, rocky soils predominate. These areas also include river bluffs, bald knobs, and glades.

1) Mammals. Although most mammals may be found anywhere within upland timbered areas, many others show a preference for the timbered borders or edge of the upland forest. One of the main reasons for this habitat preference by mammals is that a variety of foods desired by herbivores grow best along the margins of timbered areas or in clearings in the timber. Another reason, especially true in the more cultivated sections of the planning area, is that wildlife can utilize the forage offered by agricultural crops adjacent to forested areas and still have the protection and other attractions of the woodland itself. The appeal of the forest-field interface also attracts predators which prey on the herbivores. Although the predator-prey interaction in the edge is most apparent with mammals, it involves species from all animal groups - birds, reptiles, amphibians, and insects.

2) Birds. Birds are sensitive to habitat changes which produce alterations in the vegetative structure--for example, changing a forest to a field--but are relatively insensitive to changes in tree species composition within forest types (134). Thus most species which are found in an oak-hickory forest association will also be found in other forest associations. Again, as with mammals, there are exceptions. In the earlier forest associes preceding the climax stage, many forests contain only understory species or saplings of canopy species and lack the structural diversity of a mature forest. These associes will not contain the full complement of bird species that are found in a climax forest.

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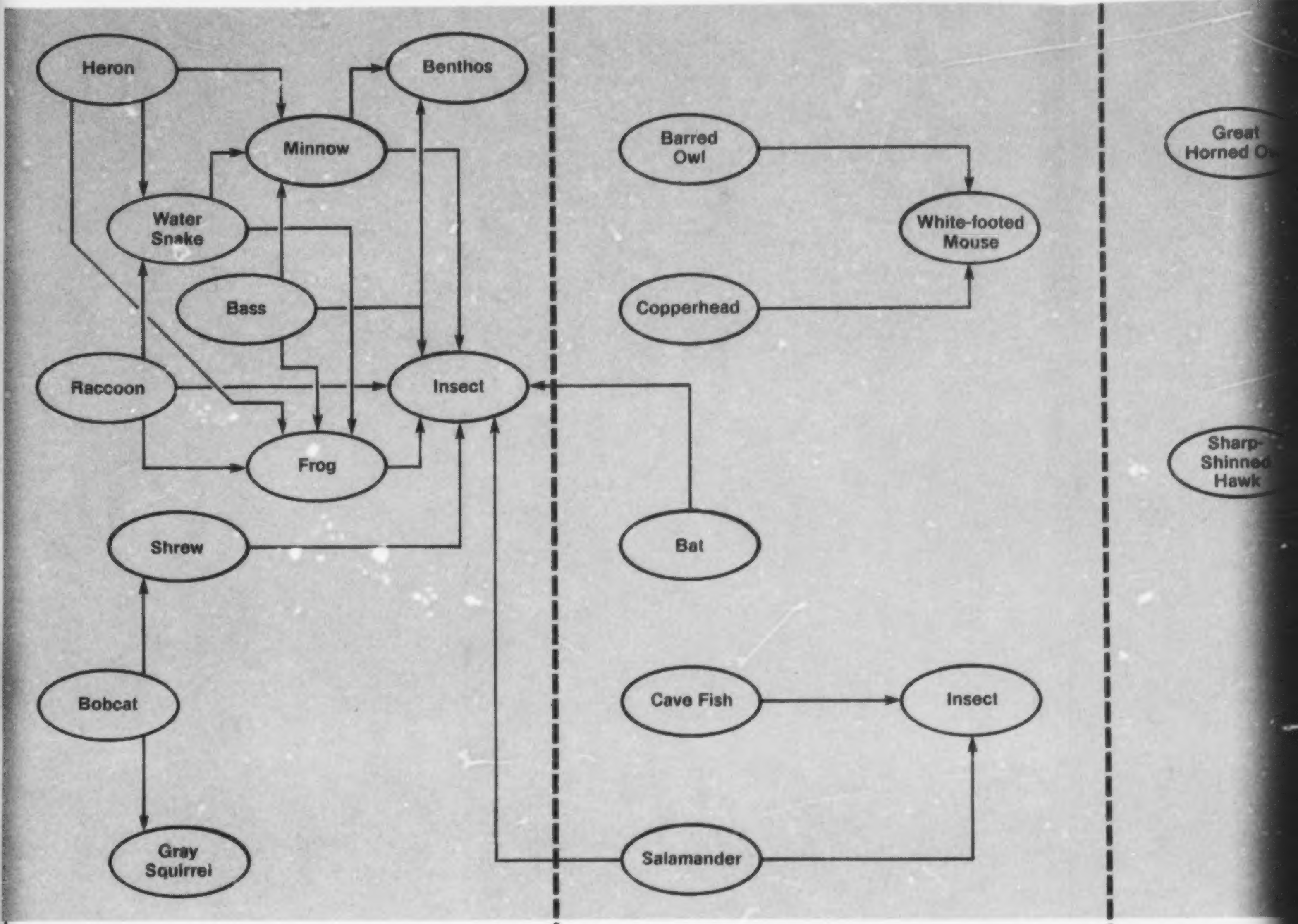
* Young squirrels depend heavily on maple and elm buds in early spring.

Figure 17



Vegetation

Buttonbush
Black Willow
Silver Maple
Green Ash
Sycamore
Arrowhead
Water Plantain

Pondweed
Water Milfoil
Coontail
Bullrush
Cattail
Spike Rush

Bottomland

Vegetation

White Oak
Red Maple
Sassafras
Dogwood
Mockernut Hickory
Blackgum
Serviceberry
Redbud

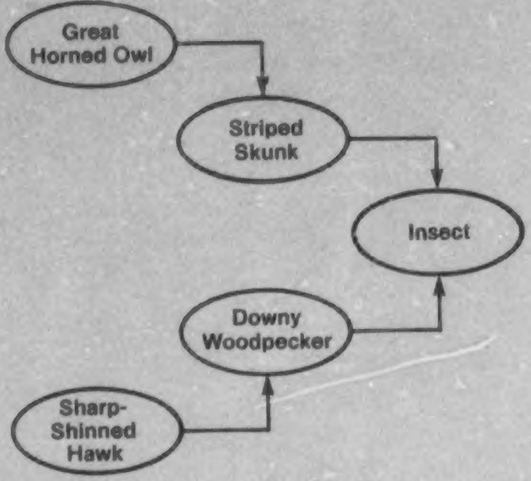
Slope And Cave

Vegetatio

Black Oak
Post Oak
Blackjack
Black Hick
Shagbark

Food Web

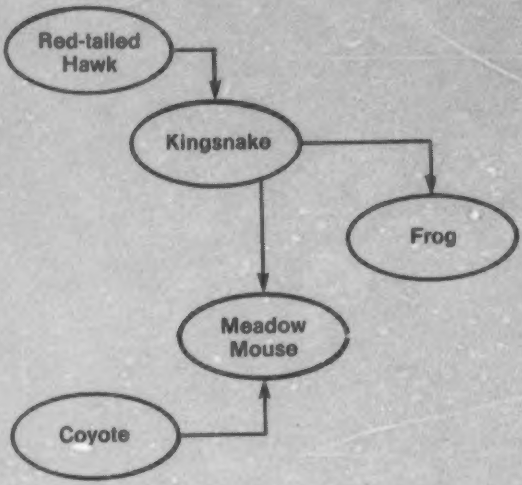
Cave



Vegetation

Black Oak
Post Oak
Blackjack Oak
Black Hickory
Shagbark Hickory

Upland



Vegetation

Fescue
Bluestem Grasses
Sunflowers
Goldenrods
Broom Sedge
Redcedar
Osage Orange

Fields

Most insectivorous species leave the woodlands in late summer and fall. Winter woods provide mice and other small rodents for predators such as the red-tailed hawk, screech owl, great horned owl, and barred owl. Nuts are utilized in the winter by turkeys, woodpeckers, and blue jays; wintering insect larvae are eaten by Carolina wrens, chickadees, titmice, and nuthatches (135).

3) Reptiles. The more drought-tolerant reptiles are found in the upland forests. The abundance of denning sites, rock outcrops, and open timbered hillsides provide optimal habitat for many lizards and snakes.

4) Amphibians. A major limiting factor for most amphibian species is water. Since standing water is usually absent from the upland forest or only seasonal in the form of spring ponds, amphibians are not well represented. Most amphibians found here have specialized behaviors to conserve moisture such as burrowing during the day and becoming active at night.

b. Bottomland Forest. Bottomland forests include sites such as floodplains and riparian communities. Wildlife found in this area is generally dependent on water, either directly, as are river- or bank-dwelling species, or indirectly, as are those species requiring moist and loose soil or vernal pools.

The edge effect is also apparent in the bottomland forest. Both density and diversity of species tend to be higher at the land-water ecotone than in adjacent uplands. The riparian strip also provides the natural corridors by which animals can move safely from one place to another (138).

Many birds use the bottomland forest. Waterfowl, herons, shorebirds, owls, hawks, hummingbirds, kingfishers, woodpeckers, and numerous perching birds add to the forest's diversity.

The most diverse group of reptiles found in a riparian habitat are the turtles. Many turtles are aquatic, seldom leaving the water except at egg-laying time or when forced to abandon drying pools, while others utilize the stream banks and downed trees as sunning spots.

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Most species of amphibians are closely linked with water throughout their life histories. All amphibians lay eggs in moist areas, even in the water itself. After they hatch, toad and frog tadpoles and salamander larvae are still dependent on moist environs. Once maturation is completed, many frogs still feed near aquatic habitats, and salamanders seek moist refuges. Still other species, such as the hellbender and the Red River waterdog, remain completely aquatic. Due to its proximity to water, the bottomland forest supports the most diversified amphibian population in the area.

c. Prairie. Prairie wildlife includes species that have adapted to rangeland or pasture, now the more dominant form of grasslands in the region, and cropland and old fields. The diversity of wildlife in each habitat is roughly proportional to the amount of food sources available, and to cover and structure of vegetation. A field of fescue used for hay and grazing will thus have few species while an old field with a mixture of trees and grasses will be capable of supporting many species. The prairie will lie somewhere in between; it has plant species diversity but lacks vertical habitat diversity.

Geographically, most prairie species originate from the West or Southwest. However, the land-use practices in much of the region's prairie-forest ecotone have altered many natural barriers which once prevented the faunas from mixing; thus, the wildlife actually has geographical affinites other than Western. Still, the mammals from the prairie dominate on open grasslands for they are better adapted to that environment. Amphibians and reptiles are poorly represented in the dry, open prairie habitats.

d. Urban. Urban habitats include cities, towns, suburbs, and exurban areas. Most species of wildlife cannot find the proper habitat in an urban environment, thus species diversity is usually low. Species occurring predominantly in urban habitats are those that have adapted to man's activities or his dwellings. Populations of some of these animals occasionally reach pest proportions and may cause problems with regard to structural damage to homes, ornamental plant and landscape damage, aesthetic degradation, human safety, and disease transmission. Another class of urban wildlife includes transients, or those species that pass through during certain times of the year. These species are generally migrating birds, and aside from winter-roosting blackbirds, they are a welcome addition to the local assemblage of wildlife.

A variety of birds are associated with man and his developments. Most notable are the European introductions, such as starlings, house sparrows, and pigeons that utilize houses directly for nests and roosts. Other birds found in urban areas are species that can successfully exploit the habitat created near man's dwellings. Different birds occur with different urban plant associations. The vegetation structure in urban habitats changes according to the age of the neighborhood.

Modification of habitat is probably the chief threat of urbanization to reptiles and amphibians. Requisite soil and water types, cover, food, breeding grounds, and hibernation areas may be altered, so that even the more adaptable reptiles are reduced in population, while those dependent on specialized habitats disappear. Water pollution discharges into urban or exurban streams that receive untreated sewage or stormwater eradicate most species for miles downstream.

e. Game. The Missouri Department of Conservation Summarizes game harvest data by zoogeographic regions. Greene and Christian counties are located in the Western Ozark Border zoogeographic region. The estimated total numbers of hunters and total harvest of wildlife species taken by hunters in the 1978-79 season, are listed in Table 11 (140). Figures for deer harvest were not given.

4. Wetlands

The U.S. Fish and Wildlife Service estimated that in 1953 there were 505 acres of wetland in Greene County and about 255 acres of wetland in Christian County with moderate value for water fowl (112). Wetland acreage was essentially in the form of stock ponds that could support waterfowl species such as mallard, teal, pintail, and scaup. With the proliferation of the cattle industry in the planning area,

TABLE 11
WESTERN OZARK BORDER TOTAL NUMBER OF HUNTERS AND GAME HARVEST

Game	Hunters	Harvest
Rabbit	17,931	133,919
Squirrel	19,436	205,455
Quail	11,912	142,132
Dove	6,458	106,646
Woodcock	752	1,442
Crow	940	4,013
Raccoon	4,013	38,433
Woodchuck	2,320	10,658
Gray Fox	752	1,379
Coyote	3,824	5,329
All water fowl	2,947	24,263

acreage for stock ponds has most likely increased two- or threefold since the original estimate. Wetlands also occur along the borders of lakes, such as were noted during field reconnaissance along the undeveloped northern shore of Lake Springfield.

Not included in the original Fish and Wildlife Service estimates were riparian and marsh areas and such karst features as spring branches, sinkhole ponds, and seeps that form wet meadows. These are now classified as wetlands by the Fish and Wildlife Service (141). The karst features, while scattered, are abundant in the planning area and support a flora and a fauna that are often unique to the surrounding aquatic and terrestrial communities.

a. Sinkhole Species. Occasionally sinkholes fill and become upland ponds. Over the course of time, these upland ponds have become rather numerous and are now scattered over the southern two-thirds of the planning area. Many of these are now used as stock ponds.

1) Vegetation. Vegetation found in unaltered sinkhole ponds includes relict species that have survived in the area because of the unique ecological niche afforded them by these natural depressions. Many of the species are known to occur otherwise only in the southeastern lowlands in Missouri's Bootheel, whereas others occur along the Atlantic and Gulf Coast plains.

2) Wildlife. Wildlife found utilizing these ponds typically consists of upland forest species, but bottomland amphibians, including spring peeper, central newt, and spotted salamander may frequent sinkhole ponds.

b. Wet Meadow Species. Wet meadows result from calcareous seepage, and flow from spring branches in valleys of the planning area. Many of Missouri's rare plants are found in this habitat, mostly relict species with ranges further to the east and north of the state. Botanists speculate that these species were carried into the warmer Missouri Ozarks during the advances of the Pleistocene glaciers. They have since persisted in these favorable microclimates, which are similar to the cooler and moist environment of their native range (121). Rare wet meadow plants found in Greene and Christian Counties are listed in Section II-D-7 below.

c. Riverine and Palustrine Species. Riverine and palustrine areas are the most predominant wetlands in the planning area. Riverine areas include braided streams where water is usually, but not always, flowing. The riverine system contains all wetlands and deepwater habitat contained within a channel and is bounded on the landward side by upland, by the channel bank, or by wetland dominated by trees, shrubs, or persistent emergent vegetation. Palustrine systems include marsh, swamp, bog, fen, and wet prairie. It also includes small, shallow permanent or intermittent water bodies--or ponds (141). The plants and animals inhabiting these systems were discussed in Section II-C-4.

5. Caves

A distinctive feature of karst topography is the cave. The origin and formation of caves were discussed in Section II-A-1. The resulting cave environment supports a unique assemblage of animals. The cave environment is usually thought of as being separated into a twilight zone near the entrance, a middle zone of complete darkness and variable temperature, and a zone of complete darkness and constant temperature in the deep interior.

The twilight zone has the largest and most diverse fauna (142, 143). Species that have been found near caves or entrances are classified as trogloxenes, and include a variety of amphibians, reptiles, birds, and mammals. Bat species that usually inhabit trees are found. Several bat species also inhabit the middle zone along with amphibians, reptiles, and some mammals which may commute to the surface. Bats use the deeper parts of the cave for hibernation or maternity purposes (144).

The unique aspects of the cave environment and its obligate or troglobitic fauna appear in the cave's deep interior. Vertebrates found here consist of only three species--the Ozark cavefish, the Southern cavefish, and the grotto salamander.

The ability of living systems to absorb, accumulate, and concentrate some pollutants is well documented. Contaminant levels, if not immediately toxic, may accumulate in the biota or sediment to levels that are damaging or even lethal to aquatic organisms or their consumers. Cave organisms, especially troglobitic species, are more sensitive to fluctuations in their stable environment than are species in an open environment. Troglobitic species have ecological and physiological adaptations which have reduced their ability to adjust to variable conditions, such as perturbations resulting from ground water contamination. Three troglobitic species occur in Fantastic Caverns - the Ozark blind salamander (Typhlotriton spelaeus), a cave crayfish (Cambarus setosus), and the Ozark cavefish (Amblyopsis rosae). The latter two species are on Missouri's list of rare and endangered species (see Section II-D-7 below). Due largely to the presence of these animals, Fantastic Caverns was identified in 1979 by the U.S. Heritage Conservation and Recreation Service as a potential national natural landmark. Although impacts to these organisms from the elevated levels of heavy metals and organic chemicals in the ground water are occurring, they are difficult to quantify.

6. Natural Areas

No designated natural areas occur within the planning area. However, a sensitive botanical area along Greene County Farm Road 160 has been identified and a great blue heron nesting colony has been located on the Little Sac River (112, 121, 146, 147). These areas are shown on Figure 16. The Missouri Department of Conservation maintains the Joe Creighton and Shelvin Rock accesses on the James River. Other Missouri Department of Conservation lands are the Little Sac Woods--892 acres located about one and one-half miles east of Sacville--and an unnamed 120 acre area with access to Clear Creek located about three miles north of Ash Grove (148).

7. Endangered, Threatened, and Rare Species

Some of the unique habitats in the planning area harbor wildlife and plants that are designated as endangered or threatened nationally or species that have been proposed for such a listing. More frequently found, however, are native plant and animal species that are rare and endangered in Missouri. The following list includes not only the obvious wildlife and flowering plants, but also lower forms of animal and plant life (146, 149). Areas where rare, threatened, or endangered species are known to occur are shown on Figure 16.

a. Invertebrates. The invertebrates comprise a large and important element in the Missouri fauna. They are so poorly known that a thorough treatment of rare and endangered species is not possible; thus, no attempt is made to indicate status. Cambarus setosus is a blind, white crayfish endemic to subterranean waters in southwestern Missouri. It has been collected in Fantastic Caverns.

b. Fishes.

1) Amblyopsis rosae*. The Ozark cavefish is listed as RARE by the State of Missouri and is proposed for federal listing as THREATENED. This blind cavefish has been collected only from underground streams in southwestern Missouri and northwestern Arkansas. Historical records indicate that they have been collected at Moore's Cave, Pfaff Cave, Fantastic Caverns, and various other caves and springs in west central and southwestern Greene County. However, the only confirmed specimens since 1980 were two Amblyopsis rosae found in Fantastic Caverns (150). Due to the generally inaccessible habitat of the Ozark cavefish, little is known about its specific ecological, behavioral, or physiological requirements. Recent collection attempts indicate that the range and population size of the Ozark cavefish may be declining, and that it may soon be absent in Greene County (150).

2) Etheostoma nianguae. The Niangua darter is also listed by the State of Missouri as RARE and is proposed for federal listing as THREATENED. This darter is endemic to Missouri where it is restricted to the southern tributaries of the Osage River from the Sac eastward (152). In Greene County, the Niangua darter has been collected in the headwaters of the Pomme De Terre River near Fair Grove. An estimated 2,300-2,700 Niangua darters exist in eight distinct popula-

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* The Southern cavefish (Typhlichthys subterraneus) has been listed as occurring in River Cave in Greene County. Recent investigations have indicated that this identification was inaccurate and that the fish in question was A. rosae.

tions over approximately 130 stream miles in the Osage River basin. They are threatened by: reservoir construction, stream channelization, accelerated erosion and sedimentation, nutrient enrichment and introduction of potential predators (152). Field investigations (Feb. 21-23, 1983) of most of the proposed wastewater treatment plant sites and receiving streams failed to discover any *E. nianguae* at these sites.

c. *Amphibians and Reptiles*. While there are no authenticated records of endangered, threatened or rare species in the planning area, populations of the State-endangered wood frog (*Rana sylvatica*) may occur. A unique species to the Ozarks, the blind cave salamander (*Typhlotriton spelaeus*), is found in Fantastic Caverns (153) and most likely in other cave systems in the area.

d. *Birds*.

1) *Buteo lineatus*. Red-shouldered Hawk - State Endangered. This hawk occupies the planning area in the winter where it occurs in moist woodlands. The species is on the Audubon Society's "Early Warning" Blue List which denotes the population is on a decline.

2) *Circus cyaneus*. Marsh Hawk - State Endangered. Although this species is still a fairly common winter migrant and county visitor in the planning area, the breeding population in the area and Missouri has dwindled to almost nothing. The Marsh Hawk is also on the Audubon Society's Blue List.

3) *Accipter striatus*. Sharp-shinned Hawk - State Endangered. In the planning area this hawk may possibly breed during the summer and occupies the area's woodlands and wood margins in the winter. This species is found on the Audubon Society's Blue List.

4) *Accipter cooperii*. Cooper's Hawk - State Endangered. The species is very similar to the Sharp-shinned Hawk and occurs in the planning area in the winter. Like the Sharp-shinned Hawk it also is on the Blue List.

5) *Sterna albifrons*. Least Tern - State Endangered. Primarily a coastal species, but nests on large, open sand bars along major rivers. The Least Tern occupies the planning area in the spring and summer. This tern is included on the Audubon Society's Blue List.

6) Limnothlypis swainsoni. Swainson's Warbler - State Endangered. Nowhere abundant, this rare and localized species is largely confined to wooded swamps and canebrushes in the southeastern U.S. While this warbler may possibly occur in the planning area, there have been no recent sightings.

7) Haliaeetus leucocephalus alascensis. Northern Bald Eagle - State Rare; Federal Endangered. Breeds in northern U.S., Canada and Alaska. This subspecies of the bald eagle winters near large impoundments and along major rivers. Eagles are seen occasionally at Lake Springfield during the winter (154) and have been reported along the James River in Christian County (112).

e. Mammals.

1) Myotis grisescens. Gray Bat - State Endangered; Federal Endangered. A highly colonial species associated with a few caves in Missouri and several other states. Caves are utilized during the summer as nurseries and during winter for hibernation. It has been recorded from cave sites in Greene and Christian Counties (112).

2) Euarctos americanus. Black Bear - State Rare. A limited survey of black bears in Missouri showed 54 occurrences in 27 counties between 1950 and 1972. If present, this species would be found in the more remote forests in the area away from human activity.

3) Mustela frenata. Long-tailed Weasel - State Rare. Long-tailed weasels occupy virtually all of the U.S. and Mexico. In Missouri, there is evidence of marked decline believed to be caused by losses of preferred habitat, i.e. woodlands, old fields and fence rows near water.

4) Lepus californicus. Black-tailed Jackrabbit - State Endangered. Formerly abundant and widespread in Missouri, but it has declined during the past two decades. The black-tailed jack rabbit prefers open pastures, hayfields, and prairies.

f. Mosses.

1) Barbula bescherellei. State Endangered. It is found on limestone and edges of creeks.

2) Grimmia teretinervis. State Endangered. It occurs on limestone rocks.

3) Orthotrichiam diaphanum. State Endangered. It grows on trees and stone walls.

g. Grasses.

1) Scleria muhlenbergii. Muhlenburg's Nut-rush - Status Undetermined. It is found in wet grounds in Greene County.

2) Carex gracillima. Graceful sedge - Status Undetermined. It grows in low woods along streams in St. Louis and Greene Counties.

3) Carex scabruta. Rough Sedge - Status undetermined. It is known from a single collection in Greene County.

h. Forbs.

1) Xyris torta. Yellow-eyed grass - State Rare. It is known from Greene, Lawrence, and St. Louis counties.

2) Tradescantia ozarkana. Spiderwort - State Endangered. It grows on rich, wooded stones and moist ledges in limestone in Christian and other southwestern Missouri counties.

3) Polygonum amphibium. Water Smartweed - Status Undetermined. Grows in water in Greene County.

4) Vicia ludoviciana. Vetch - State Rare. It is found in rocky open woods in Greene and Donald counties.

5) Ludwigia repens. State Rare. Known only from Greene County.

6) Castilleja purpurea. Purple Painted Cup - State Endangered. Grows on rocky, open ground in Greene County.

7) Prenanthes racemosa. State Endangered. It grows in wet prairies and low ground bordering streams.

8) Habenaria leucophaea. Prairie White Fringed Orchid - State Rare. It grows on moist prairies.

9) Centaurium texense. Centaury - State Rare. It is found on limestone glades and bald knobs.

10) Geocarpon minimum. State Endangered. It occurs in moist locations on sandstone glades.

11) Lesquerella filliformis. Bladderpod - State Endangered. It is found on limestone glades and rocky woods.

12) Malaxis unifolia. Green Adder's mouth - State Rare. It is found in dry, streamside woods.

13) Mimulus glabratus var. fremontii. Monkey Flower - State Rare. It occurs in springs and wet ledges.

14) Liatris mucronata. State Rare. It grows on limestone glades and bald knobs in Christian County.

15) Penstemon cobaea var. purpureus. Beard-tongue - State Rare. It is found on limestone glades and bald knobs in Christian County.

i. Trees. Ulmus americana, American Elm, is State Endangered. It occurs over the entire state, but is considered endangered due to Dutch elm disease.

E. ATMOSPHERE

1. Climate

The planning area has a continental climate with considerable variability caused by warm moist Gulf air and cold dry Canadian air which cross or meet in the area. Daily and seasonal weather changes are frequent, with extremes of precipitation and temperature in some years. Cold winters and hot summers are the general rule but departures from average conditions are common (155).

a. Precipitation. The average annual precipitation for Greene County as recorded in Springfield is about 41 inches (1940-1979). Most of the rainfall normally occurs in April, May, June, and September. Summer rains usually occur as brief thunderstorms. The least precipitation in one year was about 25 inches (1953) and the most was about 59 inches (1973). The greatest 24-hour rainfall occurred in July 1958 when about 6.8 inches were recorded. The mean annual snowfall is about 16 inches with a record of about 44 inches in the winter of 1969-70 (156). Severe droughts occurred in the mid-1930's and mid-1950's (157).

b. Evaporation. The National Weather Service shows the annual average evaporation from shallow lakes as 42 inches (158).

c. Temperature. The average annual temperature for Greene County is 55°F (13°C). The mean maximum temperature is 66°F (19°C) and the mean minimum is 46°F (8°C). Temperatures of record are -29°F (-34°C) on February 12, 1899, and 113°F (45°C) on July 14, 1954 (156).

The average frost free period extends from April 9 to October 25 (42).

d. Wind. Prevailing winds are from the south-southeast (42) (see Figure 18). Maximum wind was about 70 mph from the northwest in December 1945 (155).

e. Severe weather. Violent weather in the planning area is not unusual. Thunderstorms and tornadoes with high winds and hail generally occur during the months from May through August. Thunderstorms occur an average of 58 days per year (1945-1979) (156).

2. Air Quality

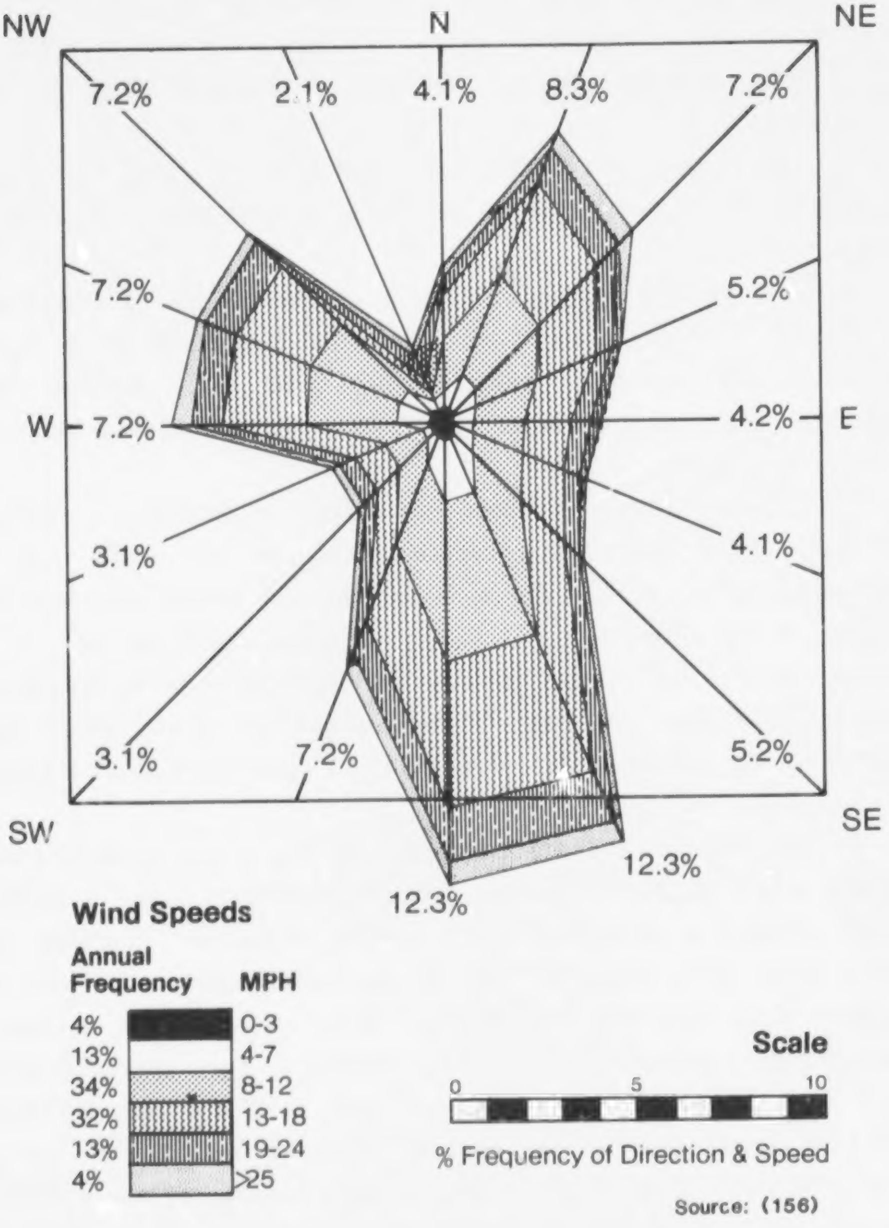
Greene County has been designated by EPA as an "attainment area" for all air pollution parameters measured (159, 160). This means that concentration values for each of the air pollutants measured in Springfield are below National Ambient Air Quality Standards. At five stations monitoring sulfur dioxide concentrations, the highest mean value for the year 1979 was 7.8 micrograms per cubic meter (ug/m^3), compared to the federal standard of 80 ug/m^3 (161). Ozone readings have also been below standards (162).

For total suspended particulates, the annual geometric mean of readings taken at four out of eight monitoring stations exceeded the federal secondary standard (161). (The secondary standard is not directly related to human health; it was established to protect animal and plant life and for aesthetics. None of the means exceeded the health-related primary standard.) However, the Springfield-Greene County Health Department was able to show to EPA's satisfaction that these high values were caused by dust blown in from outside the county and by construction projects in the vicinity of some of the stations and thus were not representative of ambient air quality in the city (162).

Annual Surface Wind Rose
Kansas City, Mo.

(Adjusted for Springfield)

Figure 18



Source: (156)

While particulate concentrations are up slightly from readings taken in the mid-1970's they are down somewhat from the late '60's and early '70's (161)

The Health Department operates eight monitoring stations for particulates, two for sulfur dioxide, and one for ozone. The department plans to add a second ozone station and one for nitrogen oxides (162).

3. Noise

Noise in Springfield is typical of a city its size. The ambient noise level in most places is determined chiefly by street traffic. Other important noise generators are airplanes landing and taking off from the airport in the northwestern part of the city and, on a temporary basis at any one site, construction projects. Outside the city limits, scattered highways and quarries are responsible for elevated noise levels in their vicinities.

F. CULTURAL RESOURCES

Greene County is one of the most intensively investigated counties in the Ozarks for prehistoric and historic sites. Nevertheless, it is very likely that highly significant archaeological sites have not yet been discovered and significant historic and architectural sites and structures have not been assessed.

This summary of prehistoric and historic cultural resources in the planning area is based on the cultural resources overview study prepared for the Greene County Sewer District's facilities plan consultant by the Center for Archaeological Research, Southwest Missouri State University (SMSU) (163). The overview discusses previous surveys conducted by the Center for Archaeological Research and others. Additional historic information was obtained from the Greene County Historical Society and the Springfield Historic Sites Board.

The Center for Archaeological Research has conducted further site-specific investigations of areas that would be affected by recommended facilities plan alternatives (164).

1. Previous Investigations

Most of the professionally guided archaeological investigations conducted in Greene County were carried out south of Springfield. Early work by Dr. Edward Shepard of Drury College dates back to the 1890's, but most study has been done since 1950. In 1955, Richard Marshall published a report discussing the surface testing of six prehistoric sites along the James River that would be disturbed by the rerouting of U.S. Highway 60. Studies related to the construction of Fellows Lake and the James River Power Plant were conducted in 1955. A brief summary of the Fellows Lake investigation indicates over 25 sites were identified, but none of these were officially recorded with the Archeological Society of Missouri (ASM). Little new material was found at the power plant site which had been extensively surface collected in the past. Dr. Harold Retallick published a brief report in 1957 on six archaeological sites located at what is now Lake Springfield. Members of the Ozarks Chapter of the ASM performed these surveys. A survey at the newly established Wilson's Creek Battlefield National Park was conducted in 1966 by Robert Bray of the University of Missouri-Columbia, and yielded prehistoric artifacts as well as Civil War era sites.

From 1972 through 1974, the James River Basin Archaeological Survey conducted archaeological research in the river basin between Kinser Bridge and the mouth of Pierson Creek. The research was directed by Dr. Robert Cooley and Michael Fuller, with participation of members of the Ozarks Chapter of the ASM and students from Evangel College and SMSU. Many new archaeological sites in Greene and Webster counties were recorded and a report nominated the Pierson Creek Archaeological/Historical District to the National Register of Historic Places.

SMSU's Center for Archaeological Research was established under the direction of Dr. Cooley and Mr. Fuller. Over 40 archaeological surveys, site testings, and excavations were conducted by the Center and others in the 1975-1981 period. The Center conducted surveys between 1975 and 1978 for the City of Springfield at the Southwest Treatment Plant and seven proposed sewer lines. The sewer line surveys revealed 116 prehistoric and historic sites, including several important discoveries. Three prehistoric sites were identified in a 1975 survey of eight city parks; five additional prehistoric sites were identified at Wilson's Creek National Battlefield in 1975; an upland prehistoric site was located during the 1976 Blackman Water Plant Survey; a prehistoric site and Civil War component were found in 1978 at the Craigmont Place housing development; 1979 testing of nine sites along the James River interceptor yielded important prehistoric findings; five prehistoric/historic sites were identified at Silver Springs Park in 1980; material from 1980-81 excavations of sites at Ritter Springs and along the Airport trunk sewer is being evaluated; and prehistoric archaeological sites were found along the edges of sinkholes in a 1981 survey near Rogersville.

In 1977, Charles Collins, a geographer at SMSU compiled data from his 20 years of amateur archaeological research, mainly along the Little Sac River, Clear Creek, and Asher Creek for the Greene County Comprehensive Plan. Upland portions of Cass, Murray, and First Robberson townships were also surveyed. These were only surface studies and many of the sites were not registered (165, 166).

More than a dozen historic resources investigations have been conducted in Greene County. At the turn of the century Dr. Shepard investigated a historic lead smelter along Pierson Creek. In the mid 1960's and early 1970's, Bray conducted extensive surveys, testing, and excavations at Wilson's Creek National Battlefield. The 1975 Airport trunk sewer survey revealed a mid-19th century grave and cabin or house foundation; the 1975 Ward Branch sewer survey located an early historic homestead; the 1975 Lake Springfield - Sequiota Creek sewer survey focused on historic cultural development in the town of Galloway; the 1975 Pierson Creek sewer line survey noted historic resources including the farming community of Mumford, Mt. Pizgah Church (1854?), early lead mining, and the camp of Henry Schoolcraft, an early explorer of Greene County; the 1976 Blackman Water Treatment Plant survey revealed the remains of the 19th century Blackman farmstead; the 1980 Silver Springs

Park investigation was concerned with evidence of a turn of the century Black community, "Happy Hollow"; the 1981 University Plaza study conceptualized the neighborhood history of the area, assessed and documented the urban architecture, tested seven historic archaeological sites, and, as a result, two historic archaeological districts were determined eligible for inclusion in the National Register of Historic Places. Studies at other Springfield locations resulted in pending proposals to create two additional historic districts - part of the Commercial Street business district and the 600 block of South Street.

2. Setting

Physiographic characteristics and climate influenced vegetation and man's material and social culture, including prehistoric and historic subsistence and migration. Prehistoric populations often settled in stream valleys and used streams as migration or diffusion routes; thus, settlement patterns or cultural adaptation may vary between drainage basins. To better understand and describe these cultural phenomena, archaeological-physiographic "regions" have been defined; these regions have been divided into drainage areas or "localities." Most of Greene County is located in the Upper Osage River locality of the Western Prairie Region or the White River locality of the Southwest Drainage Region as shown in Figure 19. The northeast portion of the county lies in the Lower Osage and Gasconade river localities of the Ozark Highland Region (167, 168).

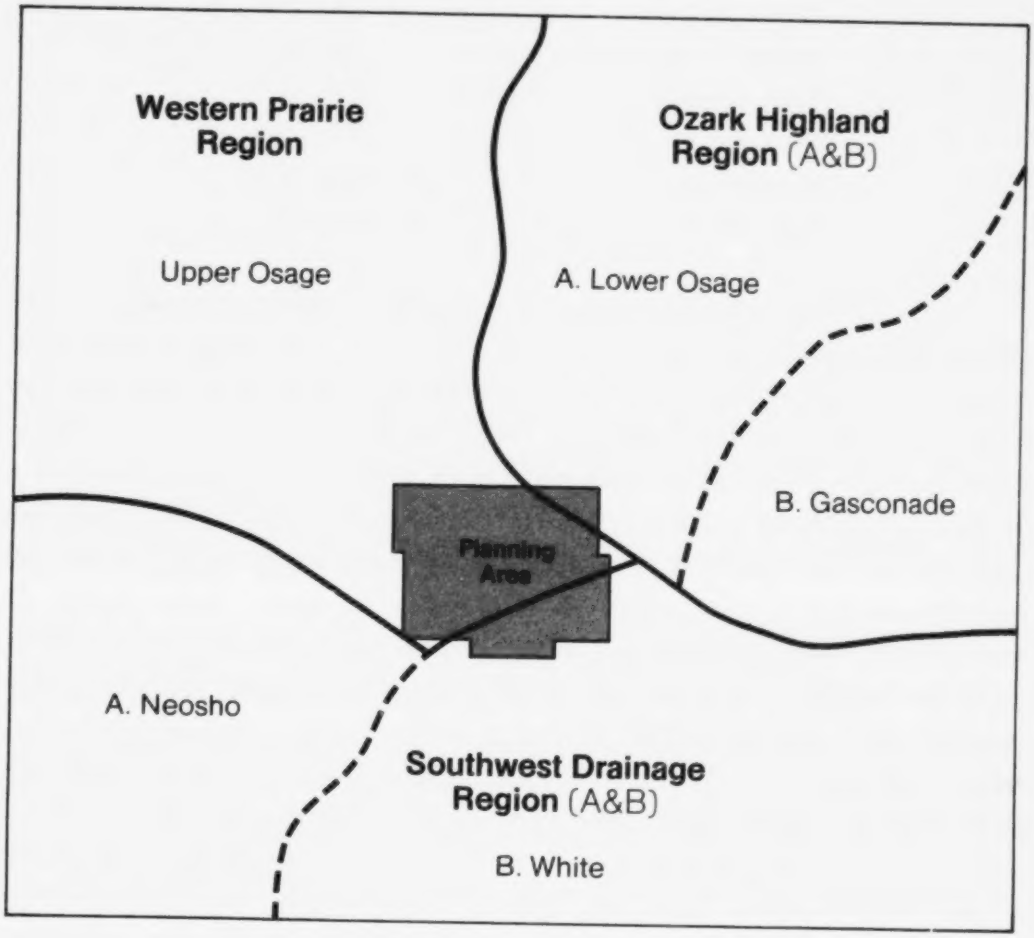
Karst topography is an important physiographic aspect of the planning area. Caves and springs provided significant resources in prehistoric times and are potential archaeological sites. The weather confronting the early inhabitants of the Ozarks was probably colder and wetter than our present climate, the warm, interglacial part of a cycle.

3. Cultural History

a. Prehistoric. The archaeological record for southwestern Missouri provides evidence of the presence of man from the Paleo-Indian period to the present (169). Chapman lists the following cultural sequences for Missouri (167):

Archaeological Regions

Figure 19



Paleo-Indian	12,000 B.C. - 8000 B.C.
Dalton	8000 B.C. - 7000 B.C.
Early Archaic	7000 B.C. - 5000 B.C.
Middle Archaic	5000 B.C. - 3000 B.C.
Late Archaic	3000 B.C. - 1000 B.C.
Woodland	1000 B.C. - A.D. 900
Mississippi	A.D. 900 - A.D. 1700
Historic	A.D. 1700 - present

1) *Paleo-Indian*. During this time, the spruce-dominated forest of a glacial period was changing to deciduous forest and prairie. Evidence of Paleo-Indian occupation in southwestern Missouri is sparse, although 43 sites have been reported in the White River basin. Three fluted points, typical of this culture, have been recorded in Greene County (because of a size differential, one may indicate Dalton instead of Paleo-Indian occupation). Bones of now extinct animals and traces of charcoal in Owen Cave, north of Springfield, have suggested a Paleo-Indian site. The rarity of sites and fluted points suggests that Paleo-Indian hunters and gatherers only briefly inhabited this area (167, 169, 170). It is also possible that many sites are still deeply buried, have eroded, or that most tools were made from perishable materials such as wood, bone, or shell (163).

2) *Dalton*. The transition to a warmer and drier climate and changing flora and fauna occurred during the Dalton Period. A variety of Dalton points have been discovered in the Southwest Drainage Region, including the James River valley. Limited information concerning the Dalton period has been found in the Western Prairie and Ozark Highland regions within the Upper and Lower Osage drainage localities (167). At least 10 Dalton sites have been identified in Greene County at floodplain, terrace, and upland (near sinks) locations.

3) *Archaic*. During the Archaic Period, subsistence activities broadened to exploit a greater variety of resources, which in turn expanded the tool inventory (167). In the James River basin, cultural change was gradual at the beginning of the Early Archaic Period

and occupants continued to be small bands of hunters and gatherers. Dalton and Early Archaic artifacts co-occur at many southwest Missouri sites and Dr. Cooley states, "It is difficult to determine whether Early Archaic people were utilizing sites previously occupied by Dalton groups, or if many of the Early Archaic people were retaining portions of the Dalton tool kit. Excavation in the Table Rock Reservoir area suggests that the latter interpretation is correct" (170). At least four sites with Early Archaic materials have been reported in the upper James River valley near Springfield. No solid evidence of Early Archaic occupation in the Upper Osage locality of the Western Prairie Region has been found. [However, the Truman Reservoir Project, which includes one of the major archaeological investigations in the Western Prairie, has not been completed. Preliminary findings show that occupation occurred from the Dalton Period through late prehistoric, with the majority of material dating to late Archaic and Woodland periods (168).] In the Lower Osage locality of the Ozark Highland Region, a definite Early Archaic complex or aggregate was found at Rodgers shelter, an archaeological site located in the same locality as northeastern Greene County but not within the planning area (167).

Middle Archaic peoples continued to be hunters and gatherers and, in adapting to a less favorable, drier environment, exploited a wider range of resources. The foraging tradition became well established throughout most of Missouri during the Middle Archaic Period. Again, most of the evidence for Middle Archaic occupation is located in the Southwest Drainage Region. At least nine sites with Middle Archaic components have been reported in the upper James River Basin, located on river terraces and uplands. Cultural contacts in the Ozark Highland Region were probably limited due to the isolation of the region. In addition, few investigations have been made on Archaic period sites in the Ozarks (163, 167).

The density and diversity of materials indicate that the most intensive prehistoric occupation in southwestern Missouri was during the Late Archaic Period (3000 to 1000 B.C.). White-tailed deer, plants, and aquatic resources were heavily exploited. It was during this wetter period, at approximately 2300 B.C., that horticulture appeared. Recent findings at Phillips Springs in Hickory County indicate that evidence of early horticulture may be available at some sites in Greene County (169). Late Archaic sites are common in the upper James River basin. Items relate to increasing ceremonial, social, and economic activities (163).

4) Woodland. In the James River basin, the Woodland cultural traits--an increase in the types of tools available to perform various functions, usually characterized by the introduction of pottery and the bow and arrow--did not appear until after 1000 B.C. and lasted well past A.D. 900. The delay in adopting a Woodland lifestyle can probably be attributed to the geographic isolation of the Southwest Drainage and Ozark Highland regions (170). Radiocarbon dates indicate Woodland occupation levels in the James River basin as late as A.D. 1200. It is probable that the Western Prairie was occupied by the foragers from the Southwest Drainage and Ozark Highland regions during the Woodland Period. The introduction of the bow and arrow and pottery vessels increased the effectiveness of hunters and expanded their ability to cook and store food. Ozark settlement patterns probably consisted of hamlets or base camps with small hunting and resource extractive sites scattered through the floodplains, rock shelters, and uplands. Rawhide clothing and various wood and fiber articles have been recovered from dry caves (163, 167, 169, 170).

5) Mississippi. As with the Woodland tradition, the Mississippi tradition began later in the planning area than elsewhere in Missouri. Changes first occurred along the Missouri and Mississippi Rivers, and then slowly spread into southwestern Missouri. The Mississippi Period is represented in the Midwest by campsites, bluff shelters, a few villages, and ceremonial centers. Most evidence of Mississipian occupation in Greene County was discovered in the James River basin, but even there surveys yielded few artifacts that could be assigned to the Mississippi Period. Occupation during this time was probably sparse (169, 170).

It has not yet been determined if the scattered artifacts in the James River basin in Greene County represent campsite-workshops of marginal Mississippian people headquartered at the mouth of the James

River or campsites for those traveling through the region. Local artifact collectors and amateur archaeologists believe that trade between the ceremonial-exchange centers at Cahokia (near St. Louis) and at Spiro (along the Arkansas River) was accomplished via the Osage trail, which passes through Springfield (170).

b. Historic. Greene County has a distinctive history in parallel with that of Missouri and the Ozarks. Its history is entwined with the rugged upper White River country of Missouri and Arkansas, the Osage Prairie-Plain of western Missouri and Indian territory beyond, refugee Indians, white immigrant settlement, various ethnic groups, the Civil War, and the reconstruction and development of the new South. Centered in Springfield, Greene County was a crossroads and warehouse serving frontier inhabitants around it. The area has relatively rich, mixed-agricultural resources, and developed through the efforts of pioneer farmers, merchants, craftsmen, miners, and manufacturers.

Systematic compilation and evaluation of the historic cultural resources in Greene County is very limited. Periods of Greene County history have been described in the following context:

Setting: The Old Ozarks Frontier
1800 - 1830: Hillmen, Hunters and Refugee Indians
1830 - 1860: The Pioneers' Greene County
1865 - 1930: Greene County in the New South Ozarks

1) The Old Ozarks Frontier. In the eighteenth century, "Aux Arc" was the backwoods of the Arkansas River and its tributaries. Early hunters and trappers travelled to the rugged Ozark highlands along the White River, a major tributary of the Arkansas. Greene County settlers preferred the more level and fertile mix of prairie and woodland to the rugged White River terrain, but Greene County was the supplier and market for the scattered population of the upper White River country throughout the nineteenth and into the twentieth century. The county served a similar function for frontier inhabitants to the west and northwest: Indians, prairie pioneers, and soldiers.

2) Hillmen, Hunters, and Refugee Indians. The Osage was the dominant Indian tribe in the planning area before 1830. At the

time of their initial contact with early European explorers, the Osage claimed all the land west of the Mississippi River to the Rocky Mountains and south of the Missouri River to the Arkansas River. By about 1800, the Osage in Missouri were mostly in the southwestern portion of the state. A treaty in 1808 with the Osage allowed the United States government to move displaced eastern tribes into their territory. Confrontations between the Osage and newcomers were inevitable (169, 170).

The Kickapoo, Shawnee, and Delaware Indians had villages along the James River and Wilsons Creek during the early 1800's (170). The Kickapoo also settled along the Pomme de Terre River (171). An 1818 treaty concentrated thousands of Shawnee, Wea, Peoria, Piankashaw, and Kickapoo in southwest Missouri by the mid-1820's.

Hillmen, hunters, and stockmen worked their way up the White River before 1820 and were the first white people in what are now Taney, Christian, and Greene counties. White settlers came to southwestern Missouri later than to many other areas of the state, probably because of its geographical isolation. Henry Rowe Schoolcraft made what is probably the first written description of the region that is now Greene County after his trip through the area in the winter of 1818-1819. He encountered trappers, hunters, and Osage Indians, as well as isolated settlements of these groups. According to Dr. Cooley, another early visitor to the area was William Fulbright, who came in 1819. He was among the numerous explorers and home seekers who later returned to settle (169). The western part of the county was explored by Nathan Boone, the youngest son of Daniel Boone. He built a cabin in what is now Ash Grove (172).

The discovery of lead ores often attracted the earliest explorers and pioneers to the Ozarks. Knowledge of lead ore in the James River valley stimulated the exploration by Schoolcraft. He was guided to several lead mines and a crude smelter, apparently the work of Indians, in the upper James River basin. For several years in the 1820's, the Delaware Indians mined lead for ammunition and trade, and miners distilled and sold alcohol to the Indians. In the late 1820's, with Delaware permission, Jeremiah Pierson settled at the head of Pierson Creek and constructed a mill and distillery (163).

John P. Pettijohn led the first group of settlers into the planning area around 1820. They settled south and southwest of the present site of Springfield along the James River (172). Settlers on the Kickapoo Prairie sometimes rented land and bought livestock from the Kickapoo and Delaware Indians. Most of the settlers left the county in the autumn of 1822 when the area was given to the Delaware Indians as a reservation (170). The 1829 Treaty of James Fork moved the Delaware farther west into Kansas. Most of the Indians were removed from Missouri by 1830 and the area was resettled by pioneers, principally from Kentucky, Tennessee, and West Virginia (169).

3) The Pioneer's Greene County. The extinction of Indian land title cleared the way for a new kind of settler, oriented to legal and orderly property ownership and improvement rather than casual squatting and claiming. John Polk Campbell, the founder of Springfield, visited the area in 1829 and returned to settle in 1830. There was a large migration of settlers into Southwest Missouri between 1828 and 1837, and Greene County was founded in 1833. In 1835 Campbell donated 50 acres for public use at the present site of Springfield. Campbell and many of the other early founders were from Tennessee, and the settlement was known as "Campbell and Fulbright Springs" until it was incorporated in 1838 (171). From the 1830's, Greene County and Springfield were the most populous, wealthy, and economically and culturally advanced areas of the whole Ozarks region.

Trade is perhaps the most important single element in the location and early development of Springfield and Greene County. Early overland routes to southwest Missouri and the White River basin from Ste. Genevieve, St. Louis, and other northeastern terminuses intersected at Springfield. Greene County's location on the boundary zone between prairie and Ozark regions and on the divide between major watersheds stimulated its role as a center for radiating trade routes. Commercial agriculture in a mixed rural economy of subsistence and marketing existed in Greene County from its founding. Principal early industries included smithys, sawmills, gristmills, and tanneries. Tobacco processing, dairying, wagon making, and other more specialized industries developed a little later.

During the period numerous social institutions became established in Greene County, including schools, churches, and newspapers. Schools were introduced in the early 1830's, and Joseph Rountree became the county's first teacher in 1832. The Butterfield stage route, carrying the first overland mail from St. Louis to the Pacific Coast, began in 1858, with Springfield as one of its stops. This was the longest stage route ever run (171, 173). Cultural expression reflected the middle and east Tennessee, town-oriented, progressive, Scots-Irish pioneers.

Slave-owning Tennessee families were a sizable and influential portion of the early pioneers. Slavery was a major political issue in the 1850's. Propertied citizens, with the most to lose in the event of secession and war, often sought to avoid such an extreme as war. Many of Greene County's leading slave-owners were prominent Unionists during the Civil War, and, after the war, their progressive views put them in an advantageous position to implement the Reconstruction or the "New South."

Many Civil War battles took place in the planning area, including the Battle of Wilson's Creek, Zagony's Charge, and the Battle of Springfield (171). The Battle of Wilsons Creek on August 10, 1861, was a crucial event early in the war. Historians generally agree that this battle was a victory for the Confederacy, but so weakened their forces that they were unable to recover sufficiently to capture Missouri (169). This was the first of many battles that involved friends and relatives fighting on opposite sides. Greene County contributed soldiers to both armies, and both sides displayed flags in Springfield (171). According to Dr. Cooley and Mr. Fuller the growth of Springfield and the surrounding area suffered under the violence of the Civil War. Bushwackers and Partisan Rangers preyed on unprotected citizens, while regular soldiers confiscated or destroyed supplies to fill their needs or to deny the enemy (170). Much of the troop movement in southwestern

Missouri followed the north-south "Old Wire Road," named for the telegraph wire strung from Rolla, Missouri, to Fayetteville, Arkansas (169).

4) Greene County in the New South Ozarks. After the Civil War, the population of Greene County again began to increase. The completion of the Atlantic and Pacific Railroad around 1870 provided a key link with other parts of the country, resulting in agricultural, industrial, and business growth, and leading to the current level of development (170, 174). Trade expanded into Kansas, Oklahoma Indian Territory, and Texas during the late 1870's. By 1881, area industries included a cotton mill, woolen mills, an iron works, a brewery, sawmills, many flour and grist mills, and factories producing furniture, carriages, tobacco, cigars, and wagons (one of which would become the world's largest). Specialized commercial farming, including wheat, corn, orchards, cattle, and other livestock, increased (163).

In contrast, some parts of Greene County, particularly the southern areas, did not adapt to progressive agriculture and modernization. Pioneer life of the Ozarks frontier continued, in many respects, in these areas, with little progress or interest in improvement (163).

4. Identified Cultural Resources

Most of the archaeological and early historical resources have been discovered on river terraces or floodplains or near perennial springs. Few archaeological surveys have been conducted in the uplands of Greene County. There are over 500 numbered archaeology sites in Greene County and more than 100 additional unnumbered sites known to local collectors (163).

a. Archaeological Sites. Archaeological sites are abundant in the James River valley. Most of the sites that contain numerous artifacts spread over a large area were occupied during more than one cultural period. One of the most significant finds during the James River Interceptor Sewer Survey was a Clovis fluted point, indicating Paleo-Indian occupation along the James River. Two other fluted points from the James River valley are in private collections.

Artifacts diagnostic of the Dalton Period that were discovered near the James River include Dalton points and plano-convex, unifacial scrapers. A majority of the Dalton artifacts found in southwestern Missouri came from terrace sites and sites situated at the base of talus slopes, with others from floodplain and upland sites. The Center for Archaeological Research has determined that most of the Dalton sites on the James River are task sites (e.g. a quarry site or hunting camp). Two Dalton habitation sites were also discovered along the James River (169, 170).

Many of the sites that yielded Dalton points also produced artifacts indicative of the Early to Middle Archaic Period. Early Archaic artifacts uncovered in the planning area include Rice Lanceolate, Graham Cave Notched, and Hardin points. Several of the Early Archaic tool types continued into the Middle Archaic Period. New tool types include the ground stone axe and the White River Archaic point, which is a small variety of the Graham Cave Notched point (170). Artifacts found in Greene County that are indicative of Late Archaic occupation include Table Rock Stemmed, Ellis, Smith Basal Notched, Stone County Square Stemmed, and Langtry points (168).

Some of the most important finds in the James River basin came from Woodland Period sites. The development of pottery, as well as the dominance of tools such as the Langtry point, the Gary point, general corner-notched points, Rice Side Notched points, and Scallorn points, is characteristic of the Woodland Period (170). In addition to possessing a distinct technology, the Woodland people in the James River Basin constructed houses, trash pits, fireplaces, and graves which have only recently been recognized (170). One site (the "Ingram Site") contains a Woodland habitation site and three mounds, one of which is a Woodland burial mound. One of the other mounds is probably also a burial mound (175). Artifacts indicate the existence of a Woodland site in the Ritter Springs area northwest of Springfield.

Evidence from the Mississippi Period indicates that occupation was probably sparse. Identifiable Mississippi Period artifacts in the planning area consist mainly of small oval projectiles and fragments of shell-tempered pottery. Evidence of classical Mississippian culture is relatively rare in the James River Basin. Dr. Cooley and Mr. Fuller state (170):

> Mississippian or marginal Mississippian influence in the James River Basin is witnessed by the few scattered projectile points and shell tempered pottery sherds from three caves. The appearance of these technological traits in the James River Basin is several hundred years after their invention or diffusion into the Mississippi River Valley. Crushed limestone tempered pottery and Woodland projectile types were associated with a hearth dated at A.D. 1200 (Fuller 1975a 8) in the Upper James River Basin. The cultural isolation of groups living in the Upper James River Basin is best demonstrated during the change from Woodland to marginal Mississippian technology. People living in the Upper James River Basin were slower than the Woodland community in the Table Rock Area to accept technological innovations. Chapman, Bray, Marshall, and Wallace (1955) obtained a date of A.D. 727 for the appearance of shell tempered pottery in the Lower James River Basin; five centuries after this date, ceramics and projectiles characteristic of the Woodland Period occupation were still being used at a site in the Upper James River Basin.

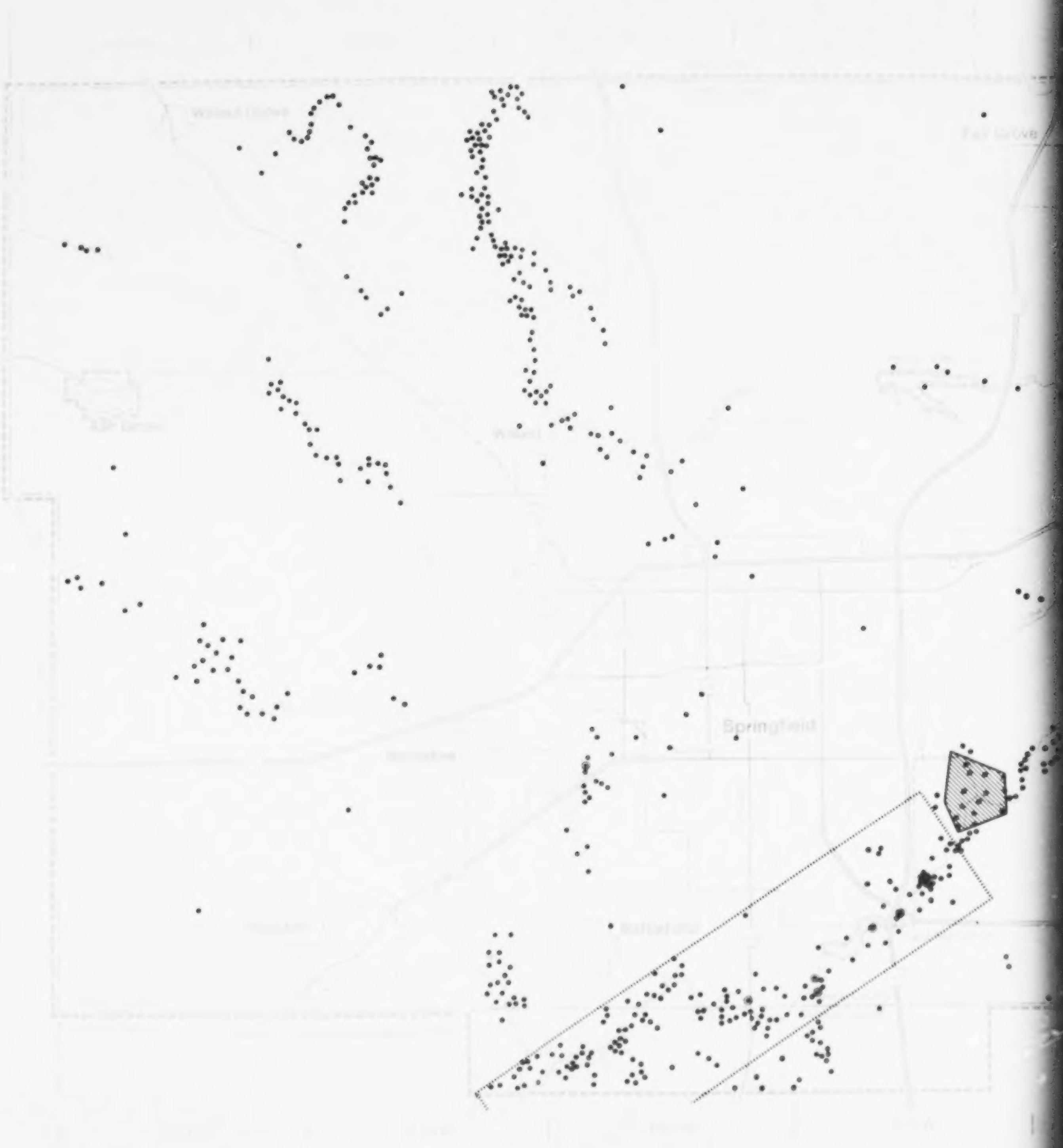
Affiliation of a number of the sites in Greene County is still unknown. The locations of confirmed sites are shown on Figure 20 (163). The sparsity of sites shown in the northeastern and southwestern sections of Greene County does not mean that archaeological resources are not present. A systematic survey of the areas is likely to uncover additional sites, particularly along waterways.

b. Significance of Archaeological Sites. Eleven archaeological sites in Greene County are listed on or eligible for the National Register of Historic Places. These include seven sites along the James River, one on Wilson's Creek, one on the Sac River, and the Pierson Creek Archaeological District with 28 known archaeological sites (176) (see Figure 20). Most sites are in areas where major construction impacts have taken place and little is known about the internal composition other than from surface surveys and excavation within construction corridors.

Additional sites are potentially eligible for the National Register. The Center for Archaeological Research recommends the establishment of a "Delaware Town Archaeological/Historical District" along the James River from the Kinser Bridge south to the northern boundary of Stone County (shown on Figure 20). Archaeological sites within this area include evidence of occupation from the Paleo-Indian to the Mississippian Period (170). Sites in the Ritter Springs area northwest of the Springfield city limits, one site on Wilsons Creek, one along Sequiota Creek, and one along the James River just north of Kinser Bridge are also potentially eligible for National Register listing (168).

c. Historic Sites. Standing structures can be studied and cared for as cultural resources in established ways. When no longer standing, they become potential archaeological sites and require archaeological strategies for examination. Despite the brevity of "permanent" settlement and building in Greene County, the remaining fraction of total structures built is small, and, in particular, the survival of antebellum (pre-Civil War) structures is rare. The traditional public interest in "famous" old buildings has broadened to include the expressions of all kinds of past people. Collection of information on the historical resources of Greene County is still in an early stage and also needs to be placed in the context of settlement and building in other areas of the United States and overseas.

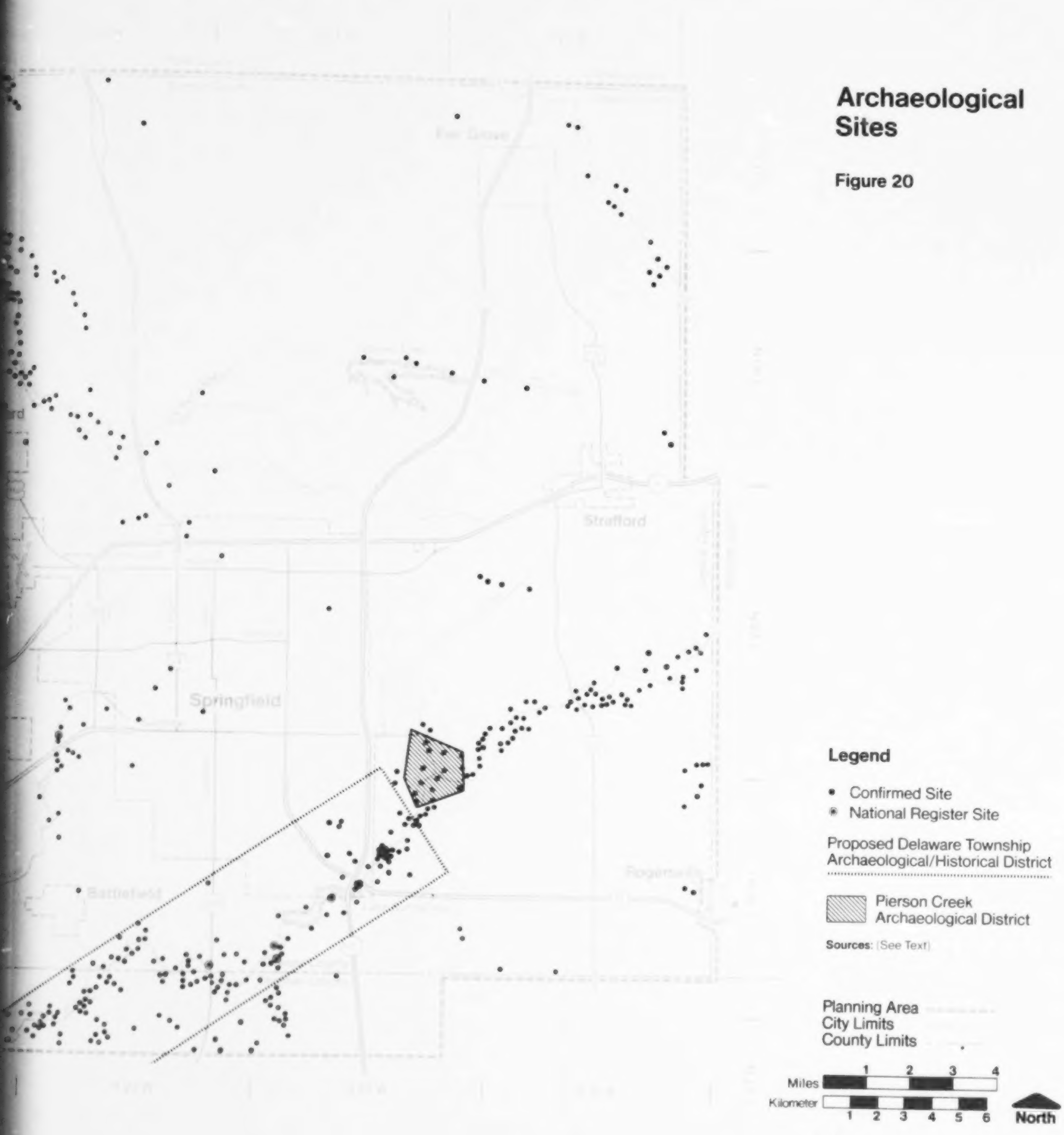
The most significant historic sites in the planning area include cemeteries, gristmills, early homesteads, Delaware Indian camps, Civil War camps and activity sites, and remains of the early railroad (170). A mill erected by William Fulbright in 1832 on Pea Ridge Creek was one of the earliest structures in Greene County. The Pierson Creek Archaeological District contains the historical sites of Henry Rowe Schoolcraft's camp in January of 1819, the first recorded discovery and mining of lead in southwestern Missouri, the remains of the Ingram Mill built in 1859, and two early cemeteries. The proposed Delaware Town Archaeological/ Historical District includes an area of intensive Delaware encampment and a Delaware trading post (170). Delaware Indian


Walnut Grove
Fair Grove
Ash Grove
Willard
Brookline
Springfield
Republic
Battlefield

Reproduced from best available copy.

Archaeological Sites

Figure 20



occupation and the Battle of Wilson's Creek were the most significant historic events in the Wilson's Creek area. The Pierson Creek District and Wilson's Creek National Battlefield are now on the Federal Register of Historic Places. The Chadwick Branch of the Springfield and Southern Railroad is still being used by the Ash Grove Lime and Cement Company. The line was laid in 1883 and abandoned in 1934 (168).

Other historic sites include the Sequiota Cave which sheltered prehistoric Indians, Civil War rangers, and possibly a grocery store (168). Historic structures are still standing throughout the county. Nathan Boone's house in the Ash Grove vicinity; the Day House, Landers Theater, the U.S. Customhouse and Post Office, the Bentley House and the Old Calaboose in Springfield; the Anderson House in Republic; are nominated to the National Register of Historic Places listing (163, 170). A number of Springfield's historic structures are on the local register.

A preliminary architectural survey of the planning area demonstrates the stylistic and functional diversity, as well as numerical potential, present. Over 50 historic sites including cabins, rural mansions, barns, schools, churches, houses and a cemetery were noted.

5. Summary

Substantial numbers of prehistoric and historic sites and artifacts have been found in Greene County. The Center for Archaeological Research at Southwest Missouri State University has conducted archaeological research surveys along many streams and rivers in the southern part of the county, but less has been recorded concerning sites in the northern part of the county and in the upland areas. The distribution of sites (Figure 20) is not representative of where sites actually exist, but reflects where archaeologists and collectors have looked thus far. Most surveys have been along major rivers and streams, but a few surveys of upland divides and upper reaches of small streams have revealed a significant number of sites, particularly near sinks and springs.

Prehistoric artifacts and sites are likely to be found wherever there is a permanent water source, such as in the flood plains

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and terraces of the James River, Wilsons Creek, Pierson Creek, and the Sac River and near perennial springs. Sites are also likely where the geological formations include stones used in tool making. There are probably hunting and burial sites, among others, in the uplands. SMSU's research in northern Christian County has shown a high density of sites in river terraces, flood plains, slopes and upland areas. The site density generally decreases with distance from a permanent water source.

Greene County's settlement and development history is well documented and generally understood at present. The built environment is not well documented or understood, and assessing potential impacts requires development of new information.

G. POPULATION

The planning area is characterized by the predominance of the City of Springfield, which is ringed by several smaller communities (see Table 12). According to the 1980 Census of Population and Housing, about 72 percent of the planning area population resides in Springfield, and on this basis, the planning area population can be defined as urban.

Greene County has experienced a relatively constant rate of change in population between censuses since 1950 as shown in Table 13. From 1950 to 1970, Springfield accounted for most of the population growth in the planning area. From 1970 to 1980, however, Springfield's percentage share of the total county population declined significantly. In fact, about 60 percent of the 32,373 persons added to the Greene County population between 1970 and 1980 is accounted for by the increase in population of areas outside of Springfield, and most of that increase was in unincorporated areas. Between 1970 and 1980, incorporated areas outside of Springfield gained in population by approximately 5,600 persons while unincorporated areas gained over 13,000 persons. However, incorporated areas other than Springfield grew at the fastest annual rate, seven percent, compared to four percent for unincorporated areas and one percent for Springfield.

Most of the population growth in the last ten years has occurred to the south and southwest of Springfield, beyond the Springfield city limits. Clay and Wilson townships, in south central Greene

TABLE 12
POPULATION OF INCORPORATED AREAS

Incorporated Area	1970 Population	% Change	1980 Population	Distance to Downtown Springfield (miles)
Ash Grove	934	24	1,157	16
Battlefield	--*	--	1,227	7
Brookline	--*	--	193	7
Fair Grove	431	100	863	15
Republic	2,411	86	4,485	11
Springfield	120,096	11	133,116	0
Strafford	491	128	1,121	10
Walnut Grove	442	14	504	20
Willard	1,018	77	1,799	8

Source: (178)

* Not incorporated in 1970.

TABLE 13
POPULATION CHANGE
1950-1980

	1950	% Change 1950-1960	1960	% Change 1960-1970	1970	% Change 1970-1980	1980
Greene County	104,823	20	126,276	21	152,929	21	185,302
Springfield	66,731	44	95,865	25	120,096	11	133,116
Balance of Greene County	38,092	-20	30,411	8	32,833	59	52,186

Source: (179)

County, have been high-population-growth areas since 1950, although Clay Township registered a somewhat lower rate of population increase in the last ten years. Most of the growth in Clay Township has occurred within the Springfield city limits. The opposite is true in Wilson Township where the unincorporated areas registered larger relative and absolute population increases in the last ten years than the incorporated areas.

Other relatively fast-growing townships are Murray and Republic. Republic Township's growth has been principally within the City of Republic, whereas Murray Township's growth has been more evenly distributed between the incorporated (Willard) and unincorporated areas.

Three townships that have shown consistent growth through the past twenty years are Brookline, Washington (southeastern Greene County), and Franklin (north central Greene County). Most of the growth in these townships has been in the unincorporated areas. Table 14 summarizes population changes in those parts of the planning area that have experienced the greatest change in the last twenty years.

An analysis of the components of population change (births, deaths, and migration) for Greene County and Springfield demonstrates that most of the population growth in Greene County has resulted from net migration (in-migration less out-migration) rather than from natural increase (the number of births minus the number of deaths). Furthermore, the share of the total population change attributed to positive net migration has consistently increased in the last thirty years, suggesting the relative attractiveness of Greene County as a place to live (see Figure 21) (179, 180).

Springfield, on the other hand, has shown increases in its base population from census to census but these increments have become smaller. The contribution of net migration to population change in Springfield has steadily declined (see Figure 22) (179, 180). In the last 10 years, the bulk of the population change in Springfield has been a result of natural increase.

Population projections for the study area and constituent municipalities were developed by Hood-Rich (the Facilities Plan consultant) in coordination with local, state and federal government agencies and are presented in Table 15. These projections assume that

TABLE 14
POPULATION OF FASTEST GROWING TOWNSHIPS IN PLANNING AREA 1960-1980

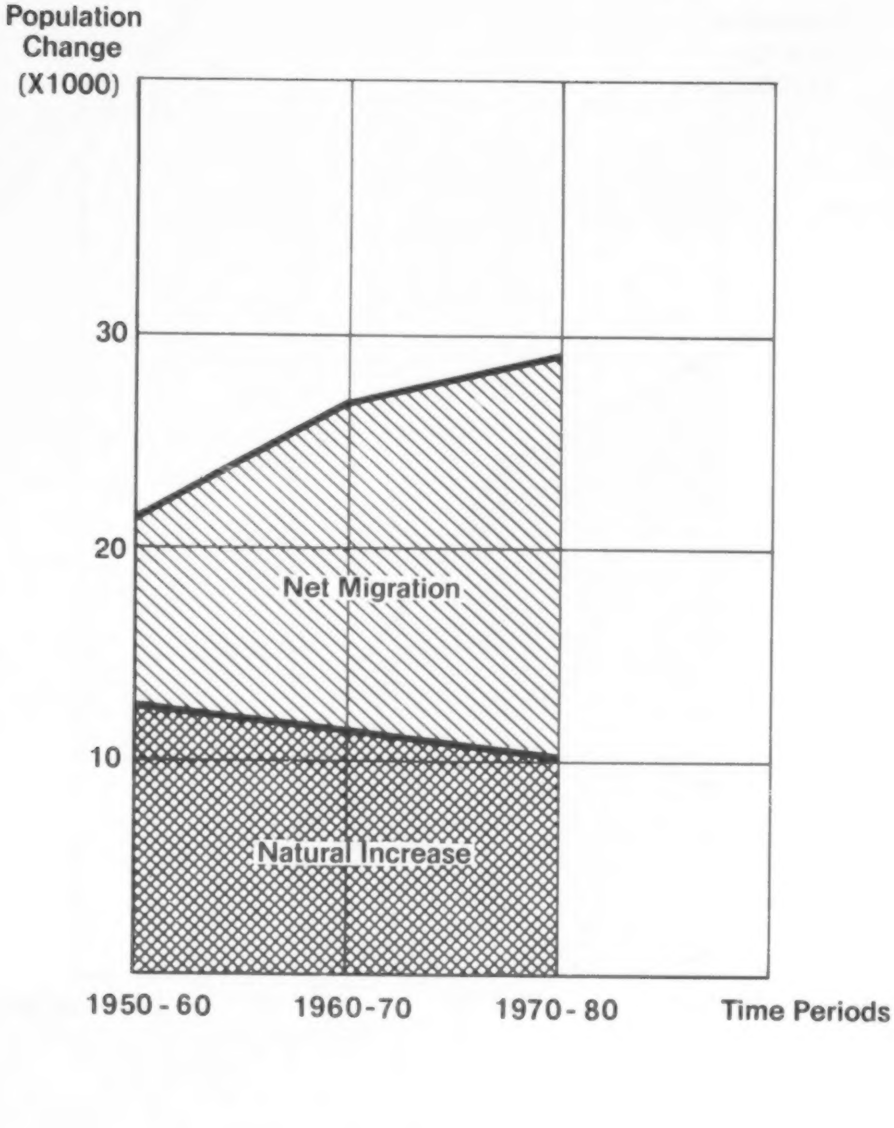
	1960	% Change 1960-1970	1970	% Change 1970-1980	1980*
Wilson	1,980	281	7,590	147	18,764
Within Springfield	365	1,251	4,932	92	9,452
Unincorporated Areas	1,615	65	2,658	205	8,099
Battlefield	--	--	--	--	1,213
Clay	3,186	163	8,376	52	12,714
Within Springfield	721	850	6,846	52	10,429
Unincorporated Areas	2,465	-38	1,530	49	2,285
Murray	843	60	1,350	88	2,539
Willard	357	156	914	79	1,635
Unincorporated Areas	486	-10.3	436	107	904
Republic	2,058	48	3,052	68	5,118
Republic	1,519	59	2,411	84	4,447
Unincorporated Areas	539	19	641	5	671

*Some redrawing of township boundaries occurred during 1980. As a result, some of the Greene County 1980 townships are not comparable (in area) with their former delineations in previous census years. The 1980 census publishes 1980 township population data using the new boundaries; the 1980 values presented in Table 14 are based on the pre-1980 township boundaries for comparability with previous census reporting. Thus, values in the last column of Table 14 will differ with values presented in Table 12 which are as published in the 1980 census.

Source: (179)

Components of Population Change For Greene County

Figure 21



Components Of Population Change For Springfield

Figure 22

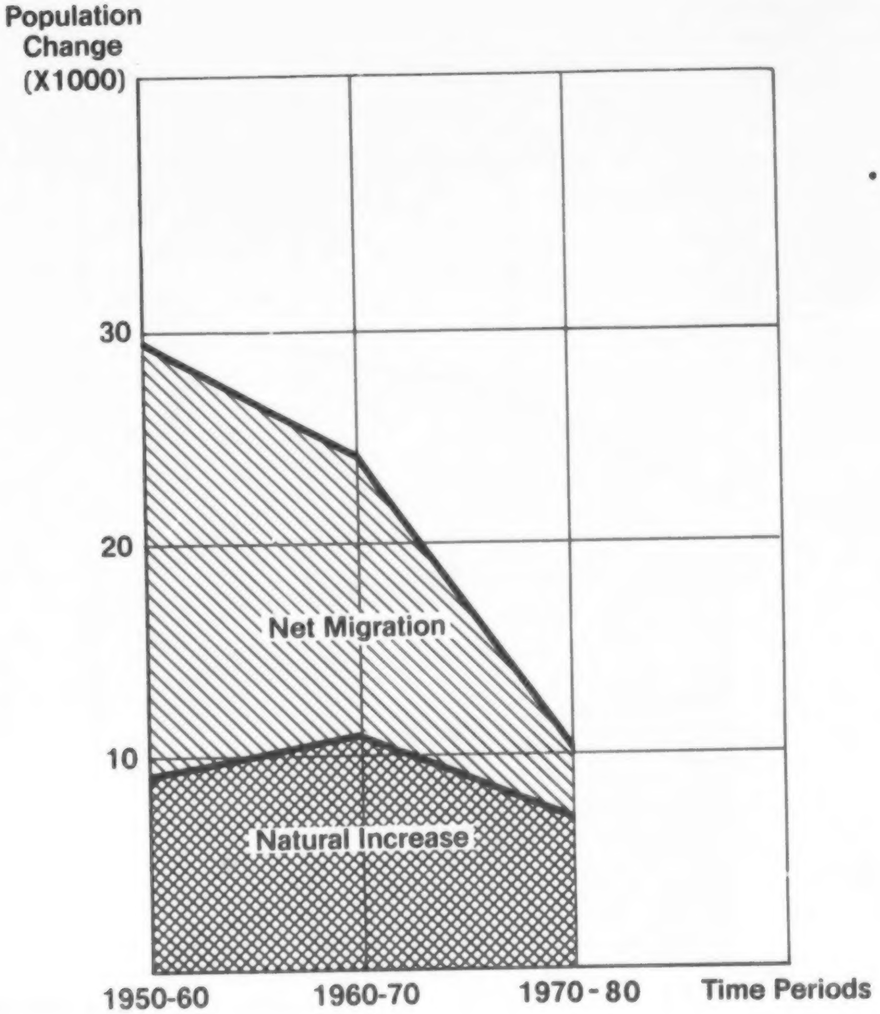


TABLE 15
POPULATION PROJECTIONS
BY INCORPORATED AREA AND UNINCORPORATED TOWNSHIP AREAS
AND FOR THE CHRISTIAN COUNTY PORTION OF THE PLANNING AREA

Entity/Year	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025
Planning Area	187,968	206,338	226,500	248,510	272,520	291,740	312,160	330,700	350,240	369,530
Greene County	185,492	203,100	222,500	243,750	267,000	285,400	305,000	322,750	341,500	360,000
Ash Grove	1,157	1,212	1,265	1,332	1,400	1,468	1,537	1,605	1,673	1,741
Battlefield	1,227	1,625	2,020	2,420	2,816	3,210	3,610	4,000	4,400	4,800
Brookline	211	212	231	254	278	298	317	330	343	356
Fair Grove	863	1,073	1,287	1,501	1,715	1,929	2,143	2,357	2,571	2,785
Republic	4,485	5,575	6,566	7,597	8,627	9,658	10,688	11,717	12,746	13,776
Springfield	133,116	139,900	147,050	154,550	162,400	168,550	174,900	181,500	188,400	195,500
Strafford	1,121	1,430	1,743	2,056	2,369	2,682	2,995	3,308	3,621	3,934
Walnut Grove	504	538	571	604	637	670	703	736	769	802
Willard	1,799	2,244	2,681	3,210	3,739	4,306	4,874	5,427	5,981	6,534
Total Greene Co. Incorporated Area	144,483	153,809	163,414	173,524	183,981	192,771	201,767	210,980	220,504	230,228
Boone Twp.	644	660	688	720	762	776	799	812	829	843
Brookline Twp.	1,057	1,086	1,123	1,165	1,217	1,256	1,291	1,320	1,352	1,386
Campbell Twp.	3,742	5,612	7,770	10,229	13,023	15,215	17,587	19,536	21,615	23,597
Cass Twp.	851	867	903	945	1,000	1,019	1,049	1,065	1,087	1,106
Center Twp.	3,548	3,652	3,814	4,001	4,238	4,342	4,488	4,579	4,690	4,795
Clay Twp.	2,341	2,828	3,389	4,024	4,750	5,316	5,937	6,434	6,977	7,489
Franklin Twp.	3,374	3,541	3,760	4,002	4,295	4,472	4,686	4,851	5,035	5,213
Jackson Twp.	2,627	2,745	2,905	3,081	3,299	3,425	3,583	3,699	3,833	3,959
Murray Twp.	957	977	1,017	1,066	1,128	1,148	1,182	1,200	1,226	1,247
North Campbell Twp.	4,106	6,916	10,179	13,877	18,078	21,374	24,953	27,877	31,008	33,996
Pond Creek Twp.	713	729	759	795	842	857	883	896	915	931
Republic Twp.	1,151	1,169	1,218	1,275	1,350	1,374	1,416	1,437	1,467	1,493
Robberson Twp.	3,445	3,524	3,632	3,763	3,920	4,003	4,107	4,179	4,263	4,346
Taylor Twp.	1,799	1,848	1,912	1,986	2,076	2,127	2,190	2,234	2,286	2,337
Walnut Grove Twp.	683	701	731	765	810	825	849	862	880	896
Washington Twp.	1,819	1,878	1,952	2,030	2,129	2,190	2,262	2,318	2,378	2,438
Wilson Twp.	8,152	10,558	13,334	16,502	20,102	22,910	25,971	28,471	31,155	33,700
Total Uninc. Area	41,009	49,291	59,086	70,226	83,019	92,629	103,233	111,770	120,996	129,772
Christian County	2,476	3,238	4,000	4,760	5,520	6,340	7,160	7,950	8,740	9,530

the planning area population growth will follow previous census trends up to the year 2000 (an average of 20 percent per decade). EPA regulations allow a 10 percent variance in excess of the control totals supplied by the State of Missouri's Office of Administration; the year 2000 population projection, is within this range.

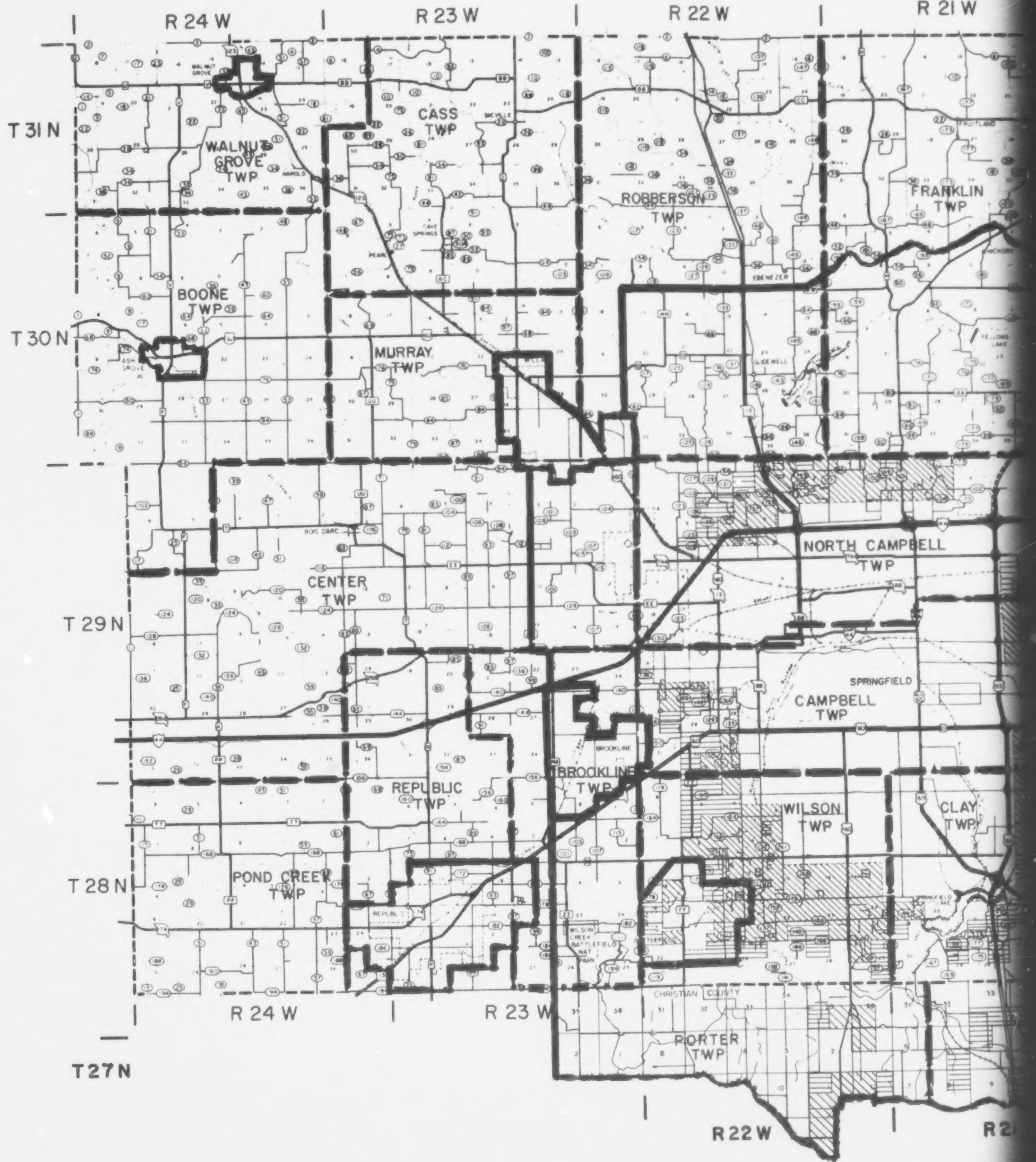
Under certain conditions, EPA regulations allow interceptor sewers to be sized for 40-year population projections. Since the Office of Administration and other planning entities have not provided projections beyond the year 2000, year 2020 projections were calculated by applying linear regression analysis (least squares) to census data and projections for the period 1960 through 2000. The resulting year 2020 projections for the planning area is 350,240. The planning area projection totals were then disaggregated among the incorporated communities and unincorporated areas within the planning area.

The MDNR had previously delineated planning areas for each of the municipalities within the Greene County Sewer District, and these became the geographic basis for final distribution of the population. These planning "subareas" are shown in Figure 23. Typically, a subarea consists of a municipality and surrounding unincorporated areas. In addition, some subareas are "nested" within a larger subarea as is the case with the Strafford subarea which is also defined as being part of the Springfield subarea. Table 16 presents the study area population projections for the planning subareas.

H. ECONOMICS AND FINANCING

1. Employment

The planning area has a diverse economic base characterized by a strong wholesale and retail trade sector (27 percent of total non-agricultural employment), manufacturing sector (20 percent), and service sector (23 percent). Most of the employment oppportunities are concentrated in the City of Springfield. Agribusiness, although not a major employer, is nevertheless an important economic activity and is a principal contributor to employment in the transportation sector and in the feed milling industry.


R 24 W
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WALNUT GROVE
WALNUT GROVE TWP
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ROBBERSON TWP
FRANKLIN TWP
BOONE TWP
ASH GROVE
MURRAY TWP
CENTER TWP
BOIS D'ARC
NORTH CAMPBELL TWP
CAMPBELL TWP
SPRINGFIELD
REPUBLIC TWP
BROOKLINE
BROOKLINE TWP
WILSON TWP
CLAY TWP
POND CREEK TWP
REPUBLIC
WILSON CREEK BATTLEFIELD NAT PARK
CHRISTIAN COUNTY
PORTER TWP
EBENEZER
PEARL
CAVE SPRINGS
HAROLD
SPRINGFIELD LAKE
FELLOWS LAKE
R 24 W
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R 21

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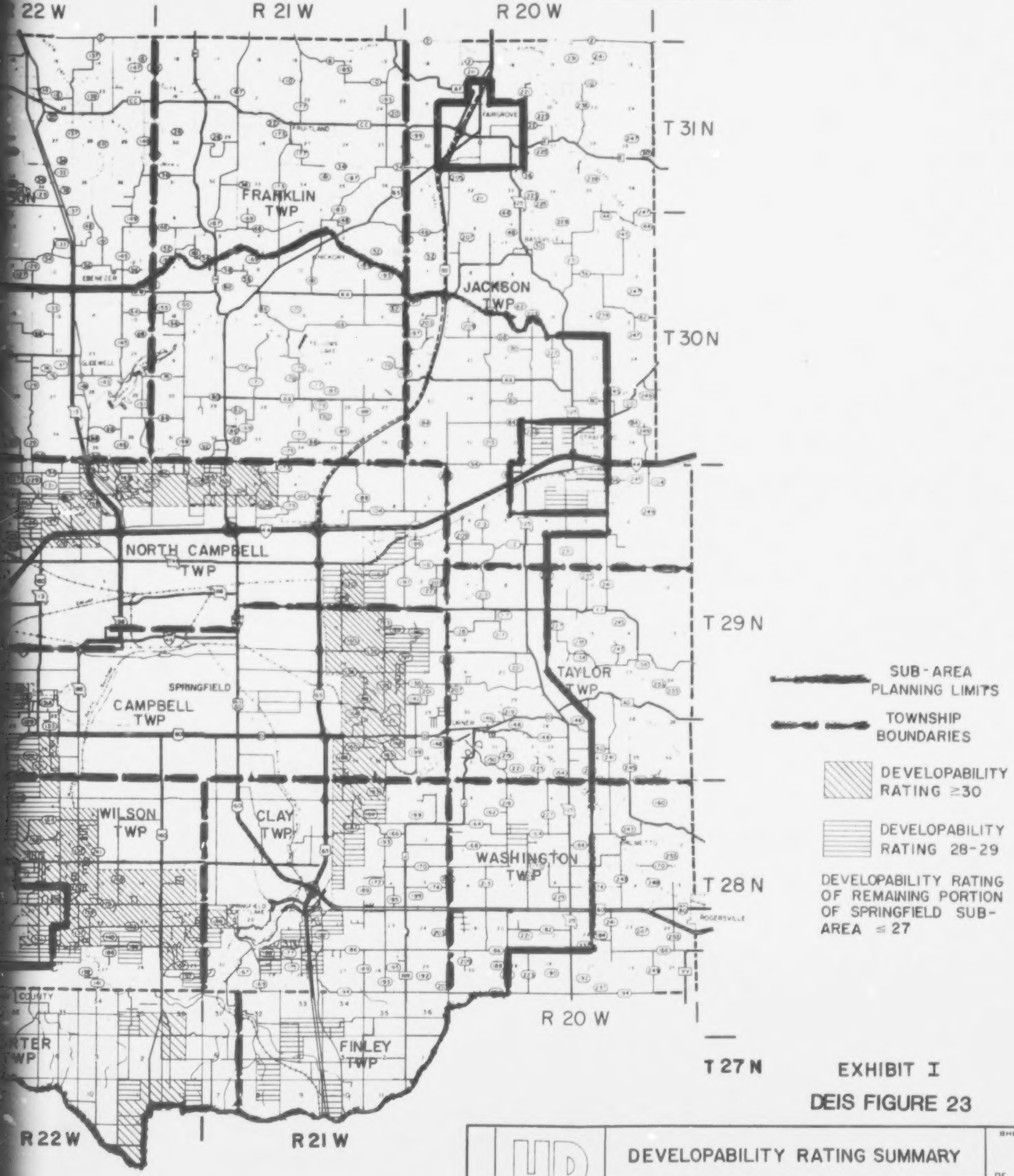

EXHIBIT I

DEIS FIGURE 23

COMM. NO.	**DEVELOPABILITY RATING SUMMARY**	SHEET OF
HR	HOOD-RICH ARCHITECTS & CONSULTING ENGINEERS 801 SOUTH GLENSTONE SPRINGFIELD, MISSOURI 65802	DATE

TABLE 16
SUBAREA POPULATION PROJECTIONS

Subarea/Year	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025
Battlefield	2,190	3,448	4,293	5,224	6,202	7,066	7,953	8,764	9,602	10,424
Brookline	513	514	533	556	580	600	619	632	645	658
Fair Grove	863	1,073	1,287	1,501	1,715	1,929	2,143	2,357	2,571	2,785
Republic	4,930	6,036	7,061	8,131	9,212	10,264	11,324	12,371	13,423	14,474
Springfield	163,223	178,700	195,800	214,500	235,000	251,200	268,400	284,000	300,500	316,800
Strafford	1,219	1,751	2,107	2,473	2,829	3,186	3,552	3,899	4,255	4,603
Walnut Grove	504	538	571	604	637	670	703	736	769	802
Willard	2,040	2,493	2,946	3,495	4,049	4,623	5,205	5,765	6,329	6,891

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Manufacturing has traditionally been the major employer in the area, although its share of employment has decreased in recent years (see Figure 24). This relative decrease in manufacturing employment has been offset by absolute and relative employment gains in the wholesale/retail trade sector and in the service sector. Government employment (civilians only) is an important job source in the planning area, but weighs less heavily in the area than it does in the state. Employment in the transportation/communications field and in the finance, insurance, and real estate sector has been fairly constant since 1972, a trend very similar to state-wide employment for these activities.

Unemployment rates in the planning area have been low relative to the national average. However, unemployment in the area has followed the same trends as national unemployment, reflecting the diversity of employment sources in the area. The planning area is not dominated by any one particular industry or firm, although there are a few firms, primarily manufacturing firms, which individually employ a significant number of persons.

2. Income

Nonfarm sources have accounted for approximately 99 percent of all direct income generated in the planning area. The manufacturing sector has contributed approximately 30 percent of all privately derived income, while the wholesale and retail sector has provided 25 percent. Services; transportation/communications; and finance, insurance, and real estate have traditionally followed with 18, 11, and 4 percent, respectively. Approximately 87 percent of all nonfarm income has historically been from private enterprise.

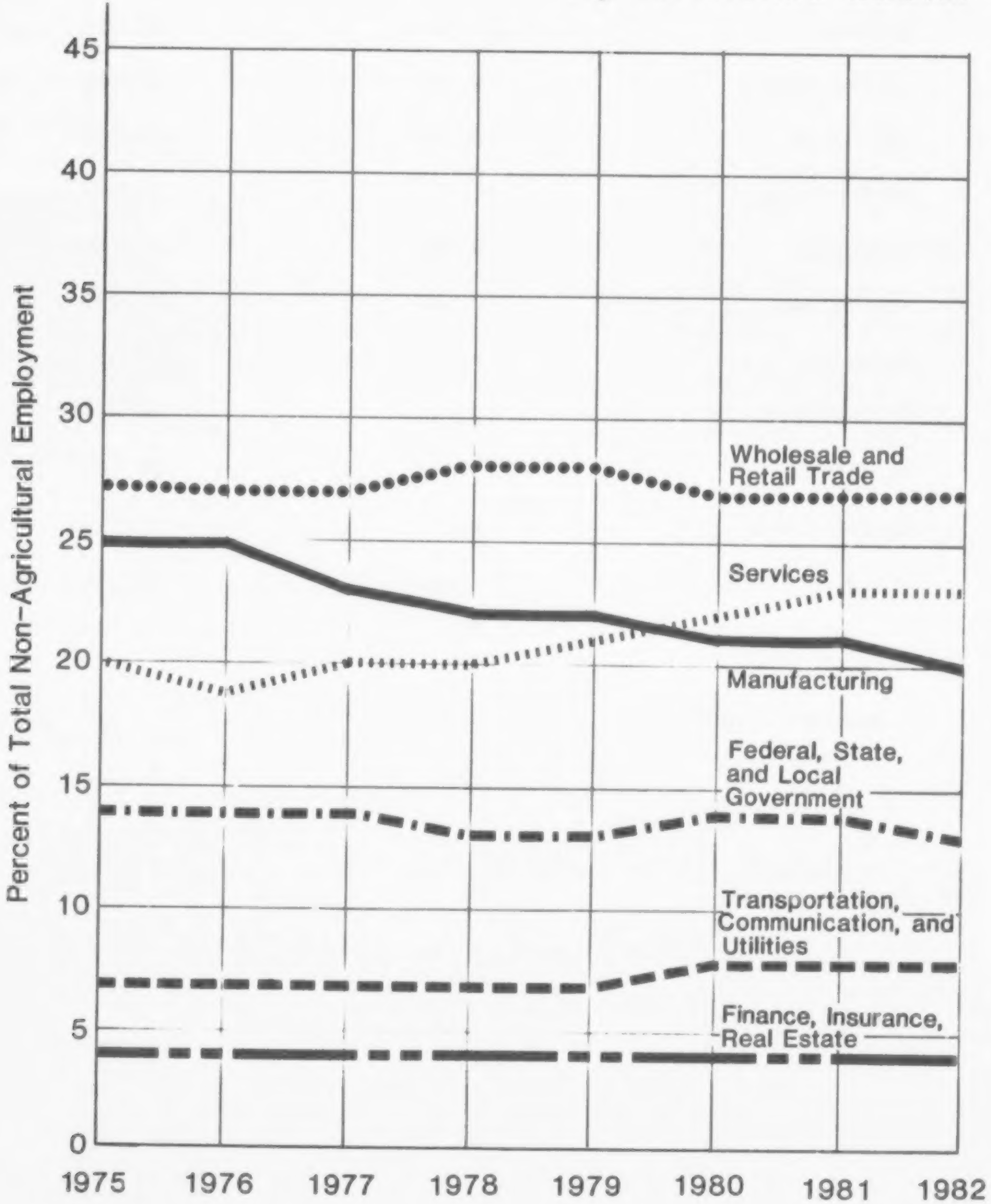
The most recent (1979) income data available from the 1980 census of population and housing is presented in Table 17. For facilities planning purposes, this income data has been adjusted using the consumer price index to estimate income changes between 1979 and 1981, the analysis base year.

3. Financing

This section summarizes the alternative methods for financing wastewater facilities available to the various governmental or administrative units within the planning area.

Figure 24

Employment Trends In The Springfield SMSA By Economic Sector



Source: (181, 182)

TABLE 17
MEDIAN HOUSEHOLD INCOME

	1979*	1981
Missouri	$15,581	$19,476
Greene County	14,380	17,975
Ash Grove	10,363	12,954
Battlefield	19,575	24,469
Brookline	16,094	20,118
Fair Grove	13,646	17,058
Republic	15,375	19,219
Springfield	13,111	16,389
Strafford	13,125	16,406
Walnut Grove	9,231	11,539
Willard	15,643	19,554

* Source: (183)

a. Bond Financing. The authority to issue bonds for wastewater facilities is available to the Greene County Sewer District, Greene County, and the incorporated cities, towns, and villages in the planning area. In general, cities may incur a total debt equal to 20 percent of their assessed valuation (not considering an additional 10 percent available for industrial general obligation bonds). The combined Greene County and Greene County Sewer District debt limitation is 10 percent of the value of taxable tangible property, while villages are limited to a 5 percent debt liability. Table 18 summarizes the current legal debt margins applicable to the construction of wastewater facilities in the planning area (185).

Two principal types of municipal bonds are used to finance major local government expenditures--general obligation bonds and revenue bonds. General obligation bonds are secured by the taxing power of the local government. They have traditionally been considered the more secure of the two types because local governments can levy taxes to meet the debt service (principal and interest) on the bonds. General obligation bonds require voter approval by a two-thirds majority before they can be issued. An important feature of these bonds is that the cost of repayment (debt service) is shared by all residents, which is acceptable when the financed project benefits the community as a whole, such as a municipal wastewater treatment plant.

When it is desired to have only the users of a facility pay for its financing and not the entire citizenry, revenue bond financing is used. Revenue bonds are repaid from revenues generated through use of the facility, usually from user fees or service charges, and require voter approval by a simple majority. They are often used for projects, such as a treatment facility serving a new industry, where it would be inequitable to distribute the cost to the entire community. Revenue bonds have become more popular than general obligation bonds in recent years, probably due to an increase in the types and specificity of services provided by local government and the frequent difficulty in gaining the greater voter approval for general obligation bonds. Also, there are no interest rate limitations associated with revenue bonds, and future rate or fee increases do not require voter approval.

TABLE 18
BONDED INDEBTEDNESS OF AFFECTED POLITICAL ENTITIES
(in $1,000)

	City or County Class	Assessed Valuation[a]	Legal Debt Limit	Debts Outstanding	Legal Margin
Battlefield	Village	2,515	126	0	126
Brookline	Village	736	37	0	37
Fair Grove	4	1,578	316	0	316
Republic	4	13,513[b]	2,703	932	1,765
Springfield	Home Rule	507,403[c]	101,500	23,192	78,310
Strafford	4	2,262	452	54	398
Walnut Grove	4	934	187	0	187
Willard	4	3,764	753	0	753
Greene County or Greene County Sewer District	1	675,000[c]	135,000		

---

[a] Source: (185) except as noted.
[b] As of December 31, 1981
[c] 1982 Assessed Valuation

b. Special Assessments and Tax Bills. The Greene County Sewer District (GCSD) is formed under Chapter 249 of the Revised Statutes of Missouri. The law provides for the payment of sewerage projects by levying special assessments and issuing special tax bills.

Tax bills function very much like general obligation bonds (except that the general public does not vote on them). The tax bill is essentially a promissory note, issued by authority of the county court to a private contractor, promising payment of principal and interest in annual, equal installments over a period of two to ten years. The funds to pay the construction portion of the debt are secured by apportioning the total cost including interest (previously limited to six percent per year) among affected property owners in the sewer district. Property already serviced by lateral sewers in the sewer district is exempt from new tax bill assessments for construction of sewers except submain or main sewers. While the law does not specifically mention treatment facilities, it is assumed that the tax bill also reflects this cost.

The contractor requires up-front capital to proceed with the project, and, in turn, sells the tax bill to a bank or other financial institution. Because a bank can obtain a better rate than six percent on its investment dollar, it would buy the tax bill at less than face value, depending on prevailing interest rates on alternative investments, very much like a bond issue sold at a discount.

In addition to tax bill assessments for construction of the facilities, the maintenance and repair costs of the project are paid by a special assessment on the assessed value of real estate within the sewer district. All property owners within the sewer district are subject to this assessment. Finally, a user charge based on the amount of water supplied to the premises is normally billed to users of the sewerage system.

One of the major issues in Greene County is the manner in which construction-related tax bills should be allocated among property owners. Since previous state law required calculating the tax on the basis of the area of the property, property owners with large tracts would have to pay a proportionately larger bill than owners of lesser acreage without regard to the use or developability of the land.

In 1983, House Bill 371 was passed by the Missouri legislature and annotates Chapter 249 by providing an alternative to the area basis for calculating tax bills and by eliminating the six percent interest rate ceiling on tax bills (184). The new law provides for apportioning the tax bills either by square footage or by the linear feet of sewer line running along or through the property for each lot, tract, or parcel of ground in the sewer district. Moreover, no assessment is made against property owners for land that is not platted unless the property owner petitions for sewer service. The bill also allows the tax bills to bear the current interest rate as approved by the county court. Changing the acreage basis by which tax bills are calculated results in a more equitable distribution of costs. Removing the six percent limitation makes the tax bills a more attractive investment instrument.

I. COMMUNITY SERVICES

1. Non-Utility Services

The City of Springfield is the major service center for the planning area. Most of the planning area communities are small and, individually, unable to provide a full range of municipal services. Table 19 summarizes several important services provided. In general, community facilities and services are not near capacity or in need of major upgrading before additional service demand can be met. Improved wastewater treatment and sewerage facilities are needed in many areas. Discussion of water supply and other utilities follows with wastewater treatment covered in Section II-J.

2. Water Supply and Other Utilities

Natural gas, water, and electricity for the City of Springfield are provided by Springfield City Utilities. Utilities for the remaining portions of Greene County are furnished by several private companies and publicly owned utilities. City Utilities provides gas to Battlefield and electricity to Brookline. Empiregas, Gas Service, and Aurora Gas extend service to Willard, Walnut Grove, and Republic. Empire District Electric, Ozark Electric, and Southwest Electric provide service to Willard, Republic, Walnut Grove, Fair Grove, and Battlefield.

TABLE 19
GREENE COUNTY MUNICIPAL SERVICES

Governmental Unit	Police	Fire	Health Services	Schools	Parks/Recreation	Cultural
Greene County	Sheriff Dept. 12 Officers 30 Volunteers	Volunteer Fire Departments from 11 Communities; and Civil Defense Unit of 22 Volunteers	Springfield-Greene County Health Department; see Springfield City	Ten School Districts	Two Park Areas: a Two-acre Area and a Children's Playground	County Library
Battlefield	Provided by Greene County	Membership Fire Department	See Springfield City	See Republic	--	--
Brookline	Provided by Greene County	Provided by Battlefield	See Springfield City	See Springfield	--	--
Fair Grove	One Police Officer	Volunteer Fire Department	See Springfield City	Fair Grove R-X One Elementary, one Middle, one High	Ten-acre Park Just Outside City Limits	--
Republic	5 Uniformed Police; 8 Reserve Officers	20 Volunteer Firemen with Assistance from City Employees	See Springfield City	Republic R-III 2 Elementary, 1 Middle, 1 High; 1980 Enrollment of 2,084	4 Parks, 1 Municipal Swimming Pool	Branch Library

TABLE 19
GREENE COUNTY MUNICIPAL SERVICES (continued)

Governmental Unit	Police	Fire	Health Services	Schools	Parks/Recreation	Cultural
Springfield	186 Uniformed Police Personnel plus 36 Staff Personnel	204 Personnel, 10 Stations	4 Hospitals, 1,740 Hospital Beds; 150 Beds Proposed; 121 Full-time Primary Care Physicians; Medical Facilities and Personnel Service Entire SMSA	Springfield R-XII, 44 Elementary, 8 Junior Highs, 5 Senior Highs, 1 Vocational-Technical Center	45 Parks and Recreation Centers (5,561 Acres) Also 1,200 Acres of Parkland and Open Space, 5 Municipal Swimming Pools, 3 Public Golf Courses; 36 Tennis Courts, 19 Baseball Diamonds, Picnic and Playground Areas	Springfield Art Museum, 1 Main Library, and 4 Branch Libraries
Strafford	1 Police Chief, 1 Deputy	Volunteer	See Springfield City	Strafford R-VI 1 Elementary, 1 High 920 enrollment in 1980	--	--
Willard	3 Officers, 2 Reserve Personnel	Volunteer	See Springfield City	Willard R-II; 3 Elementary, 1 Middle, 1 High; 1980 Enrollment of 2,412	1 20-Acre Park	--

In addition to the Springfield system, various municipal, water-district, and privately owned water systems serve the public in Battlefield, Fair Grove, Republic, Strafford, Walnut Grove, and Willard. Some surrounding and rural areas are served by these public systems, while remaining areas and Brookline residents obtain water from individual wells. Springfield City Utilities obtains its water from both surface and ground water sources and the other systems use wells.

a. Springfield Water System. The water supply sources for Springfield are Fulbright Spring, McDaniel and Fellows lakes, the James River, and several deep wells. Treatment is provided by the Fulbright and Blackman water treatment plants.

Fulbright Spring, the original central water supply source for Springfield, has been used since 1883. The Valley Water Mill Reservoir was acquired for water supply in 1892, and supplements flow to Fulbright Spring through piped releases to a natural underground channel that connects the two. A well adjacent to the Fulbright Water Treatment Plant is also used as a source of raw water to the plant.

McDaniel Lake is an impoundment on the Little Sac River and was completed in 1929. The McDaniel Raw Water Pump Station and two transmission lines convey water about two miles to the Fulbright Plant. Fellows Lake was completed upstream of McDaniel Lake in 1957. It provides for controlled releases down the Little Sac River to McDaniel Lake, where the water can then be pumped to the Fulbright Plant. The Fellows and McDaniel lakes system is Springfield's primary supply source and provides most of the reserve supply during prolonged dry weather.

The Blackman Water Treatment Plant and associated raw water intake was completed in 1980. Withdrawals from the James River are limited by permit from the U.S. Army Corps of Engineers to balance water supply and fish and wildlife flow needs. The minimum downstream flow requirement is relaxed during drought to allow greater water supply withdrawal. Raw water is pumped about one mile from the intake to the Blackman Plant (46, 186).

An 11-mile pipeline and other facilities are being constructed to link the Blackman Plant and Fellows Lake were completed in 1983. The pipeline and an intake structure and pump station at Fellows Lake make it possible to pump excess James River water to Fellows Lake and water from Fellows Lake to the Blackman Plant. This allows optimized use of water available from both the Little Sac and James River watersheds. It provides the Blackman Plant with a source of water when the James River is low, and will also allow quicker refill of Fellows Lake after a dry period by supplementing inflow with James River water.

Additional sources are three routinely used wells (Nos. 10, 11, and 12) that were obtained through the purchase of smaller systems; a well near the Blackman Plant that is reserved for peaking use; and five deep wells around McDaniel Lake, drilled during the 1950's drought and reserved for extreme emergencies only. Based upon a recurrence of the severe 1952-1957 drought, the yield of the Springfield water sources are:

Drought Yield (MGD)

McDaniel and Fellows Lakes	12.8
Fulbright Spring/Valley Water Mill	3.0
Fulbright Well	2.0
Wells 10, 11, and 12	1.9
James River	4.6
Sub-Total	24.3
Blackman-Fellow Pipeline (not complete)	2.9
Total	27.2

The Fulbright Plant, built in 1937-41, has a nominal capacity of 24 MGD and actual peak capacity of 30 MGD. The Blackman Plant has a rated capacity of 30 MGD. Both plants provide complete conventional treatment consisting of flocculation, settling, filtration, and disinfection. High service pumps deliver treated water to the distribution system.

City Utilities established a program for conservation of water, gas, and electricity in 1977, and a water conservation plan was passed as an ordinance in 1981 (46,186). The program includes conservation workshops and other educational activities on the efficient use of water and water consuming appliances, brochures on water saving devices and do-it-yourself leak repairs, and the provision of thousands of shower-head flow restrictors. The water conservation ordinance requires water saving plumbing fixtures on new construction. Water conservation is also an important effect of City Utilities' water supply user charge system which includes comprehensive metering and a relatively high rate structure. As a result, overall water sales in Springfield of about 100 gpcd and water demand of about 130 gpcd have been significantly less than the commonly referenced national figure of 150 gpcd for municipal water use.

Water demand forecasts project average water use to increase from 20 MGD in 1982 to 25.1 MGD by 1990; and peak daily use to increase from 34 MGD to 42.6 MGD by 1990 (186). Based on the forecasts, a new source of raw water will be needed by the mid 1990's, and several alternatives are being considered.

b. Other Water Systems (187, 188). The communities of Republic, Strafford, and Walnut Grove own and operate their own water systems. The Republic system serves about 1,700 metered customers or 4,500 persons, all residing within the city limits. Water is supplied by three wells that can pump about 2.1 MGD; system storage is 0.375 MG; and water use averages 0.6 MGD (189). The Strafford system serves about 360 customers or 1,120 persons, all within the town. Two wells have a capacity of 0.4 MGD; system storage is 0.1 MG; and water use averages 0.08 MGD. Some Strafford residents have their own wells (190). Walnut Grove has one well and a 0.05 MG storage tank to serve 240 metered customers or 400 persons. Pumping capacity is about 0.4 MGD and water use averages 0.055 MGD. The system is in need of new service lines and fire hydrants (191).

Greene County Public Water Supply District #1 provides service to 700 customers or 2100 persons in Battlefield and surrounding areas within several miles of town. The system has two wells with a supply capacity of 0.8 MGD and generally pumps about 0.25 to 0.30 MGD, although use increased to 0.4 MGD during the hot summer months of 1980. A new 0.25 MG storage tank and an older 0.05 MG tank provide storage (192). Greene County Water District #5 supplies water to about 305 metered customers or 720 persons in Fair Grove. The system has one well with a capacity of 0.25 MGD and is adding another (193). Water use averages 0.035 MGD and there is a 0.055 MG storage tank. The Willard Water Company, a private concern, can pump 0.6 MGD and has two wells and a

0.05 MG storage tank. The system serves 625 customers or 1500 persons in the city and the immediately surrounding area (194). Greene County Water District #6 has one well, an 0.075MG storage tank, and serves 135 customers or 360 persons in the Bois D'Arc area.

The Strafford, Walnut Grove, and Willard systems, and water districts #1, 5, and 6, do not disinfect or provide any other water treatment. Fluoridation is the only treatment at Republic (187).

The Village of Brookline and other areas of Greene County, not within one of the service areas described above, obtain water from individual wells.

J. EXISTING WASTEWATER TREATMENT FACILITIES

There are three major municipal treatment plants in the planning area, serving mainly the incorporated areas of Springfield and Republic. (Ash Grove also has a central collection and treatment system but is not in the planning area and is thus not discussed below.) A number of subdivisions, mobile home parks, and other developments have their own treatment systems. The remaining population is served by on-site treatment facilities, mostly septic systems.

The two Springfield plants have experienced problems with wet-weather flows exceeding treatment and storage capacities and the resultant bypassing of partially treated sewage to the receiving streams. All three treatment plants have had problems to some degree in meeting their National Pollutant Discharge Elimination System (NPDES) permits. The Republic and Northwest plants are both overloaded and frequently do not meet secondary treatment effluent standards, much less the more stringent losing stream standards which apply to each. Major problems have been related to malfunctioning septic systems. Surfacing sewage and contamination of the groundwater are frequent occurrences in a number of areas in the county.

1. Municipal Treatment Facilities

a. Greater Springfield Area. The majority of residents in the City of Springfield and some of the neighboring developments are served by two wastewater treatment plants--the Northwest Treatment Plant and the Southwest Treatment Plant. These two plants and two small plants serving subdivisions are operated by the City of Springfield. The small plant serving the airport area was taken out of service in 1982 with completion of the Airport Branch trunk sewer and pump station for delivering wastes to the Northwest Treatment Plant. The location of these facilities and the areas they serve are shown in Figure 25.

The Northwest Treatment Plant serves the part of Springfield lying north of the St. Louis-San Francisco railway tracks. The Southwest Treatment Plant serves the rest of the city, which includes about 85 percent of Springfield's population and land area. Both plants also serve some areas outside the city limits. Although sanitary sewer service is provided to nearly all parts of the city, only about 85 percent of the population is actually connected to either system. The other 15 percent uses on-site systems or small package plants.

Current flows to the Southwest and Northwest plants include substantial industrial, commercial, and institutional contributions. Estimated dry weather flows to the plants are summarized as follow (1):

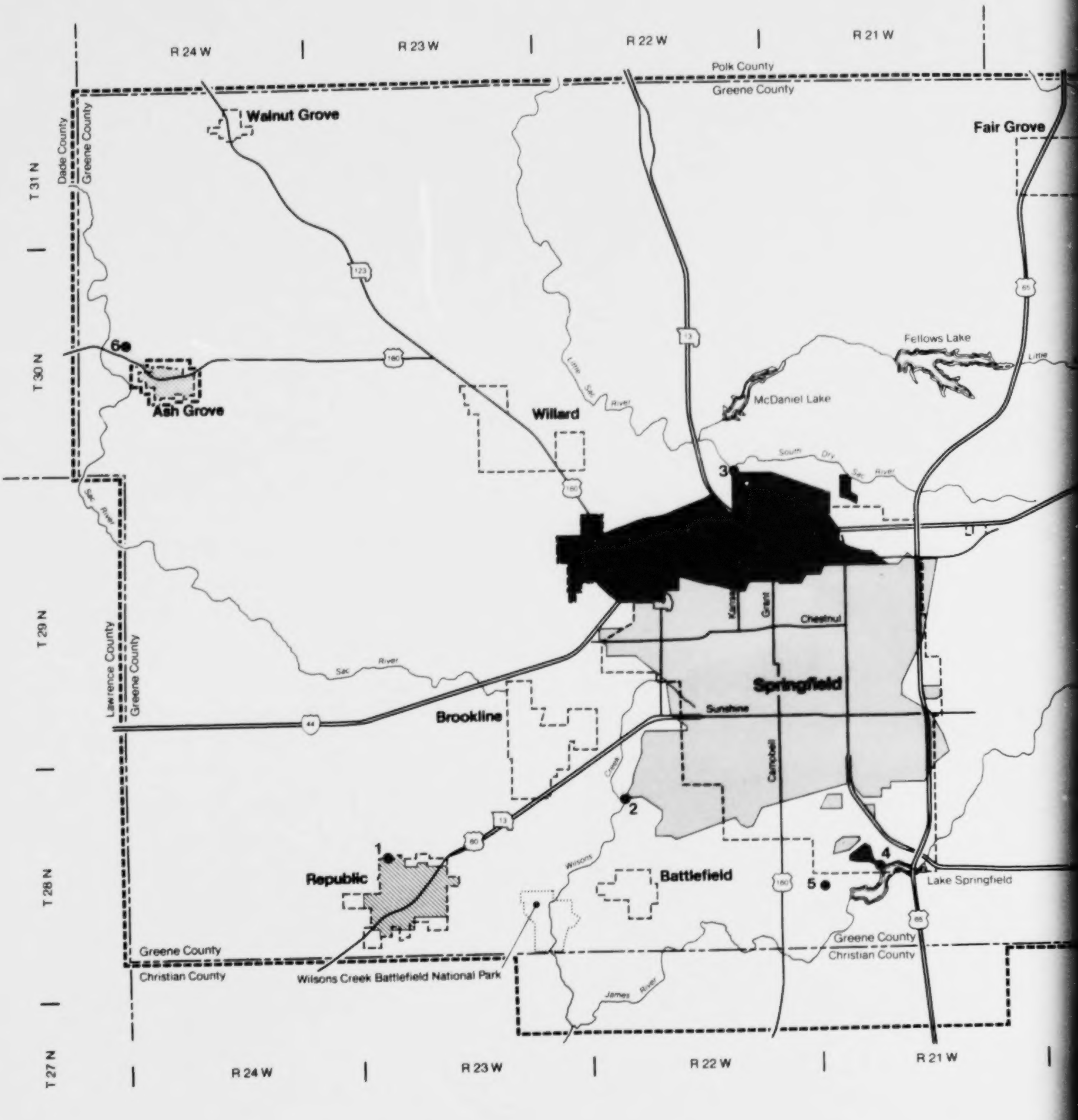
	Dry Weather Flows (MGD)	
	Southwest Plant	Northwest Plant
Domestic	6.80	1.19
Industrial	1.96	0.27
Commercial	1.79	0.45
Institutional & Government	2.77	0.46
Infiltration	3.68	-
TOTAL	17.0	2.4

Twenty-one major industries with a combined flow of 1.96 MGD discharge to the Southwest Plant, and three major industries with 0.27 MGD to the Northwest Plant. These industries include food processing, metal plating, electronics, soft drink bottling and laundries. Average flows from institutions (including schools, hospitals, and prisons) and government facilities are estimated at 2.77 MGD and 0.46 MGD to the Southwest and Northwest plants, respectively. Because of the industrial and institutional components, influent wastewater characteristics differ from normal domestic wastes.

Springfield's sanitary sewer system dates back to 1894 and the collection systems for both treatment plants contain some very old sections, with some pipe over 80 years old. Pipe sizes vary from 4 to 60 inches in diameter. Before 1950, most sewers were constructed of vitrified clay pipe (VCP) with lime mortar joints; some large sewers were brick and mortar. Since that time, reinforced concrete (RCP) or ductile iron (DIP) pipe has been used for lines larger than 18 inches in diameter and VCP or polyvinyl chloride (PVC) pipe for the smaller lines. Jointing materials for VCP has been mortar, hot bitumastic, PVC, and polyurethane. RCP joints have been cement mortar or rubber, and DIP and PVC have been rubber. The old brick sewers were replaced with RCP during the late 1950's because of joint deterioration and structural failures.

The sewer system is maintained by the Public Works Department, which routinely cleans it about once every two years. The sanitary system is not designed to handle storm drainage. Efforts have been made to locate and eliminate sources of extraneous flows in the most troublesome areas. However, the sewer system still has a large amount of infiltration/inflow (I/I), increasing the amount of wastewater the system must convey to the treatment plants. During wet weather, the wastewater flow exceeds the capacity of some pipes resulting in overflowing manholes and basement flooding. Causes of the excess I/I include deterioration of old pipe joint materials, faulty construction, illegal connection of roof and foundation drains, manhole deterioration, and damage from abuse. Even in dry weather, significant amounts of infiltration occur, particularly in the southern system, since a number of the larger sewers are at depths greater than the perennial water table. The two major plants serving the Springfield are further described below.

1) Southwest Treatment Plant. The Southwest Treatment Plant, built in 1959, was initially designed as a secondary treatment plant. Improvements were made and completed in 1977 to upgrade the plant to advanced treatment. The existing facility includes flow measurement, screening equipment, facilities for storage of wastewater when the hydraulic capacity of the plant is exceeded, an aerated grit chamber, primary sedimentation basins, pure oxygen aeration tanks, secondary sedimentation basins, nitrification tanks, final sedimentation basins, dual media filters, ozonation facilities for disinfection, sludge thick-



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R 23 W
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Polk County
Greene County
Walnut Grove
Fair Grove
Dade County
Greene County
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123
65
13
Fellows Lake
Little
McDaniel Lake
Little Sac River
6
160
T 30 N
Ash Grove
Willard
South Dry Sac River
3
160
Sac River
Lawrence County
Greene County
T 29 N
Kansas
Grant
Chestnut
Springfield
Sac River
Brookline
44
Sunshine
Campbell
Wilsons Creek
2
13
60
1
4
Republic
Battlefield
160
5
Lake Springfield
T 28 N
65
Greene County
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Christian County
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Wilsons Creek Battlefield National Park
James River
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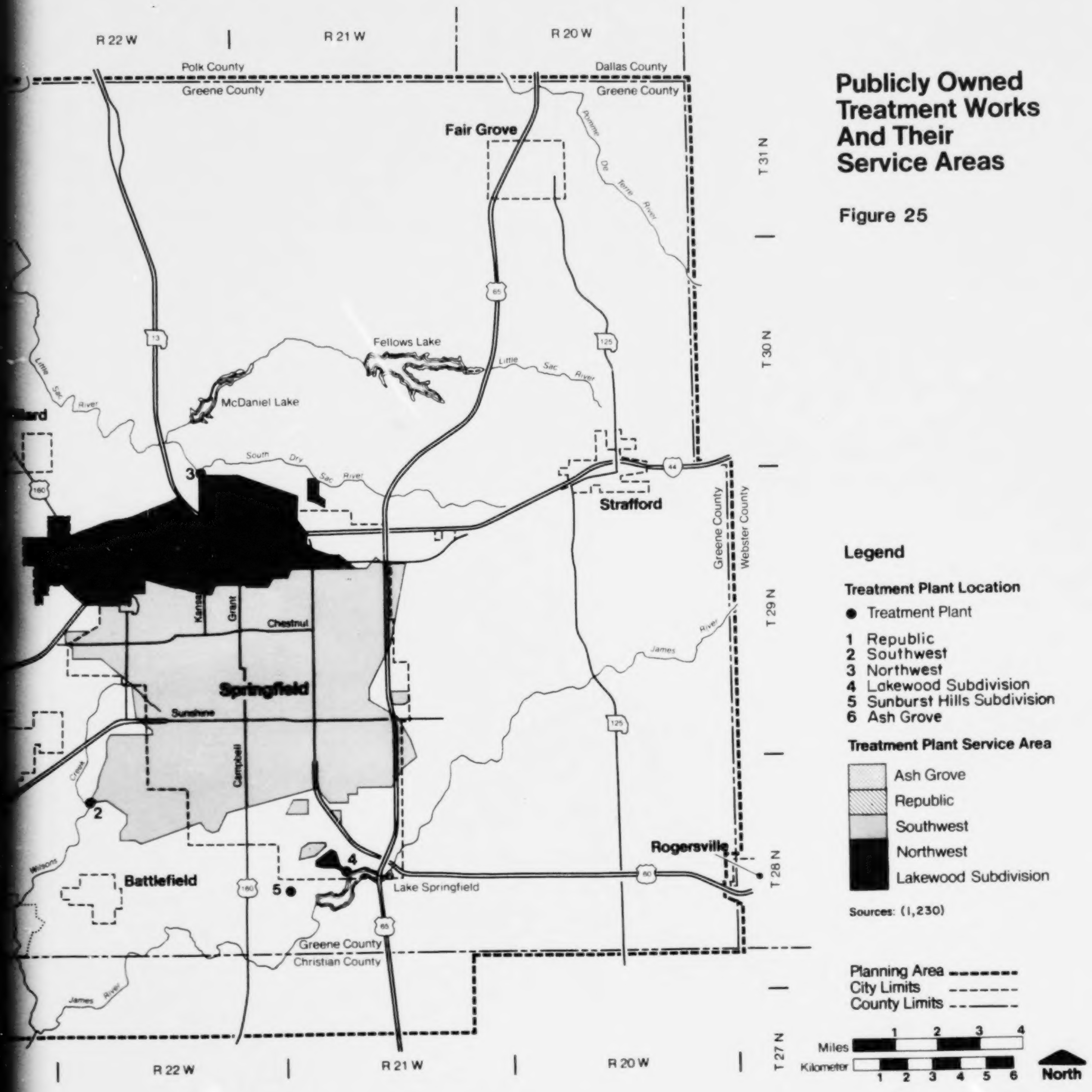

Publicly Owned Treatment Works And Their Service Areas

Figure 25

ening equipment, anaerobic sludge digesters, vacuum filter sludge dewatering, and complete laboratory facilities. Sludge is disposed of by spreading on nearby farmland, either as liquid sludge or filtered sludge cake.

The Southwest Treatment Plant has an average design flow of 30 MGD. From 1979 to 1981, average flow to the plant was 25.4 MGD, with some monthly averages exceeding 46 MGD. The peak day flow to the plant was 75 MG. The hydraulic design capacity is 42 MGD. A summary of waste loads and effluent characteristics for 1979 to mid-1982 is given in Table 20.

Effluent limitations for the Southwest Plant are based on a 1973 waste load allocation study of Wilsons Creek and the James River. The study showed normal secondary treatment would not be adequate and monthly/weekly average permit limitations are 10/15 mg/l BOD, 10/15 mg/l SS, 2/3 mg/l ammonia, 200 fecal coliform colonies per 100 ml, and DO of at least 6.0 mg/l or 80 percent of saturation. The fecal coliform limits apply because Wilsons Creek is a losing stream and the James River is classified for contact recreation. The 10/15 mg/l SS limit was established before the State's adoption of a 15/20 mg/l SS limit for losing streams.

Effluent quality of the Southwest Plant is very good and, except for fecal coliform, is generally in compliance with permit limits. During the period from 1979 to mid-1982, effluent BOD has consistently met the limits: SS were above limits (ranging from 14 to 22 mg/l) for several periods in 1979 and one week in 1982; ammonia was above limits (ranging from 2.3 to 3.9 mg/l) for seven weekly or monthly periods, mainly during the colder months; and fecal coliform were above the limit on 136 days (about 11 percent of the time)(1).

The high fecal coliform levels are mainly due to operational problems with the ozone generators; when several of these malfunction, there is an inadequate supply of ozone for complete disinfection, particularly during periods of high flow from infiltration and inflow (I/I).

I/I during wet weather are excessive. When the plant and 41 MG storage facilities are unable to handle the excessively high flows, the overflow is disinfected and discharged to Wilsons Creek.

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TABLE 20
AVERAGE WASTE LOAD AND EFFLUENT CHARACTERISTICS
SOUTHWEST TREATMENT PLANT

Parameter	1979	1980	1981	1982 (6 months)
Flow (MGD)				
- Average Day	28.1	22.4	24.4	27.8
- Peak Day	65.8	57.5	49.0	74.7
- Dry Weather Weekday	17.0	17.0	17.3	17.1
- Dry Weather Weekend	13.0	13.0	13.2	15.7
BOD				
- Influent (mg/l)	184	239	242	188
- Influent (lb/day)	43,200	44,400	49,200	43,600
- Effluent (mg/l)	5	3	3	3
Suspended Solids				
- Influent (mg/l)	161	181	200	189
- Influent (lb/day)	37,800	35,300	40,700	43,700
- Effluent (mg/l)	6	3	3	4
Ammonia Nitrogen				
- Effluent (mg/l)	1.9	0.9	0.4	0.9
Annual Rainfall (inches)	43.4	23.3	39.6	20.6

Source: (1)

This occurs on the order of once or twice a year and more during wet years. When normal conditions return, the stored wastewater is pumped to the head of the treatment plant for full treatment. Problems of surcharging trunk, interceptor, and smaller sewers are also caused by excessive I/I.

2) Northwest Treatment Plant. The Northwest Treatment Plant was designed as a secondary treatment plant. It was constructed in 1935, and modified in 1957 and 1973. The existing facility includes screening equipment, flow measurement devices, an aerated grit chamber, primary sedimentation basins, facilities for the storage of wastewater when the hydraulic capacity of the plant is exceeded, aeration tanks, nitrification tanks, secondary sedimentation basins, chlorination facilities, anaerobic digesters, and some laboratory facilities. Digested liquid sludge is spread on nearby farmland.

The Northwest Treatment Plant is the smaller of the two major plants, designed for an average flow of 3.5 MGD and a hydraulic capacity of 5.25 MGD. For the 1979 to June, 1982 period, average flow to the plant was 3.2 MGD, with monthly averages as high as 5.4 MGD. Peak day flows have exceeded 7.5 MGD on some occasions. A summary of waste loads and effluent characteristics for 1979 to mid 1982 is given in Table 21.

Effluent limitations for the Northwest Plant are based on a 1973 waste load allocation study of the Little Sac River and South Dry Sac River. The study, based on an average discharge of 3.0 MGD, showed normal secondary treatment would not protect aquatic life. The resulting daily effluent limitations are 15 mg/l BOD, 15 mg/l SS, 200 fecal coliform per 100 ml, and dissolved oxygen (DO) of at least 6.0 mg/l or 80 percent of saturation. The fecal coliform limits apply because the South Dry Sac River is a losing stream.

Although the averages indicate that the plant produces good quality effluent, daily results show the plant failing to meet permit limitations, mainly BOD and SS, 38 percent of the time (1). Fish kills occurred in 1982 that were allegedly caused by the plant effluent. Wasteflows are near plant design capacity and excess I/I flows cannot be treated satisfactorily. During periods of peak flow, the 4.5 MG storage basin does not have the capacity to hold all of the excess, and the

TABLE 21
AVERAGE WASTE LOAD AND EFFLUENT CHARACTERISTICS
NORTHWEST TREATMENT PLANT

Parameter	1979	1980	1981	1982 (6 months)
Flow (MGD)				
- Average Day	3.5	2.6	3.5	3.5
- Peak Day	7.5	7.1	7.1	6.9
- Dry Weather Weekday	2.3	2.3	2.3	2.5
- Dry Weather Weekend	1.9	1.8	1.9	2.3
BOD				
- Influent (mg/l)	158	215	166	137
- Influent (lb/day)	4,630	4,700	4,800	4,000
- Effluent (mg/l)	12	13	12	13
Suspended Solids				
- Influent (mg/l)	160	170	160	137
- Influent (lb/day)	4,700	3,710	4,600	4,000
- Effluent (mg/l)	17	18	15	15
Annual Rainfall (inches)	43.4	23.3	39.6	20.6

Source: (1)

overflow is discharged to the South Dry Sac River with only primary sedimentation and chlorination. This occurs on the order of once or twice a year, usually during the spring months. When flow to the treatment plant decreases, the stored wastewater is pumped to the head of the plant for complete treatment. These problems do not fault existing facilities or operation since the plant was not designed to meet current effluent limitations.

Another serious problem has been flooding after very heavy rains. Nearby swollen streams topped the flood protection dikes and completely inundated the plant in both 1978 and 1981. Pumps, motors, and other equipment were severely damaged and the plant was out of full operation for several weeks. Chlorination was the only treatment during much of this time.

The Northwest Plant discharge permit expired in December 1982 and was not renewed because of the inability to meet effluent limitations. Until a new or upgraded facility is built, interim improvements to increase effluent DO are being implemented. Also, a new wasteload allocation study has been conducted by MDNR (66). Preliminary results show that nitrification* of plant effluent will be required. Effluent requirements are expected to be approximately 20 mg/l BOD, 20 mg/l SS, 2 mg/l ammonia, and 6 mg/l DO. Effluent filtration will not be required at this time. Pollutants from landfills and other sources affecting the Little Sac River were also considered in the wasteload allocation study and found to be potentially significant.

b. Republic. The City of Republic's central wastewater collection and treatment system (see Figure 25) serves about 4100 people or 90 percent of the incorporated area and population. The wastewater is domestic in nature and includes wastes from commercial establishments, schools, and small industries.

The Republic wastewater treatment plant was designed as a contact-stabilization activated-sludge plant with a design flow of 0.75 MGD. As actually constructed and operated, the plant is a conventional activated-sludge (extended aeration) treatment plant followed by an eight acre three-cell lagoon. The current average flow to the plant is about 0.5 MGD, with monthly averages as high as 1.4 MGD.

---

* Biological oxidation of ammonium (NH_4+) to nitrate ($NO_3=$) to reduce the oxygen demand and toxicity to aquatic life of effluent.

The existing facility includes a bar screen, an aeration tank, a secondary sedimentation tank, a three-cell lagoon, chlorination equipment, an aerobic digester, and laboratory facilities. The plant discharges into Dry Branch, a tributary of Pickerel Creek and the Sac River. A summary of wasteload and effluent characteristics is given in Table 22.

Large wet-weather flows from I/I are a problem. Peak flows of over 5 MGD approach the capacity of the pumps to convey the sewage to the treatment plant. During low flows, however, some pumping stations are under-utilized, operating only one hour per day. This allows the wastewater to become septic and makes treatment more difficult.

The plant has serious problems in meeting secondary treatment standards for BOD and SS. The septic condition of the incoming sewage, the incomplete nature of the plant's construction and excessive I/I are major reasons for its inability to meet permit limitations. The polishing lagoon is unable to improve the effluent from the treatment plant to an acceptable level before discharge. Since the Dry Branch has been found to be a losing stream, a new or expanded facility would have to meet stricter losing stream standards.

2. Private Treatment Facilities

There are a number of private treatment facilities scattered throughout Greene County which serve subdivisions, mobile home parks, schools, commercial establishments, and industries. Except for some of the industrial treatment facilities, none of the private facilities are very large. Each serves its area with collection systems independent of any municipal system. The most common type of private treatment system is a lagoon with intermittent discharges. There are also many private package treatment plant systems.

In general, the small treatment facilities are not required to meet as stringent effluent limitations as the municipal treatment plants. Also, the operation and maintenance of the private facilities is not as thorough as for the municipal plants, and sampling programs are minimal. In some cases, lagoons are unattended and the embankments have become overgrown with brush.

TABLE 22
AVERAGE WASTE LOAD AND EFFLUENT CHARACTERISTICS
REPUBLIC TREATMENT PLANT

Parameter	Typical	4/79-6/80
Flow (MGD)		
- Average Day	0.50	0.63
- Peak	6.85	--
BOD		
- Influent (mg/l)	250	--
- Influent (lb/day)	1,043	--
- Effluent (mg/l)	LT 40	26
Suspended Solids		
- Influent (mg/l)	--	--
- Influent (lb/day)	--	--
- Effluent (mg/l)	LT 40	38

LT: less than

3. On-Site Treatment Systems

The remainder of Greene County - that portion of the population not served by municipal or private treatment facilities - uses on-site treatment systems for wastewater disposal. The most common type of on-site system is the conventional septic system, consisting of a septic tank and an adjacent absorption field. Other types of on-site treatment found in Greene County are aerated septic tanks with absorption fields, and a septic tank with an elevated absorption field (a mound system), located in Strafford.

A properly operating septic system provides very adequate treatment of the wastewater from a single home or a group of homes. Solids accumulate in the bottom of the septic tank, where the sludge is partially stabilized by bacteria. Grease and other light particles float to the top of the tank and are trapped. The remaining liquid flows from the tank to the absorption field and into the surrounding soil through perforated pipes. As the wastewater flows downward, it is purified by bacterial activity and reactions with the soil. There have been many problems with septic systems in Greene County. Surfacing sewage and infiltration of the groundwater by partially treated effluent from septic systems are common occurrences in some areas (93). These problems can be traced to several factors: poor design and construction, irregular maintenance, and poor soil suitability. Design, construction, and maintenance are discussed below, and soils are discussed in Section II-A.

Current design and construction practices in Greene County often lead to malfunctioning septic systems. For example, improper laying of the pipe results in uneven distribution of the tank effluent to the absorption field. Inadequate area for the absorption field is another problem, leading to premature clogging of the field after a short operating period.

Septic tanks should be pumped out on a regular basis to prevent solids overflow and clogging of the absorption field. However, there are no requirements in Greene County for regularly scheduled maintenance of septic systems. General practice is to pump out septic tanks only when the homeowner has problems with surfacing sewage or when wastewater backs up into the house. By that time, the absorption field has been damaged and pumping out the septic tank provides only limited relief. Pumped septage is disposed of at the Northwest Treatment Plant in Springfield or on nearby farmland.

K. ENERGY

Gas and electricity use by the existing Springfield wastewater treatment facilities are presented in Table 23. The Southwest Treatment Plant consumes large amounts of electricity in producing oxygen and ozone for use in its process operations. The two plants use approximately equal amounts of gas.

Energy use within the planning area is partly determined by land-use patterns. Although there are certain exceptions, it is generally considered more energy-efficient for land uses to be clustered rather than scattered throughout a large area. Scattered development requires essential services to be delivered over greater distances, which requires greater energy use. Water and natural gas must be pumped farther, using more electricity. School buses, police, and fire vehicles must travel farther, using more gasoline.

Residents in rural subdivisions must travel greater distances, using more fuel, for such activities as commuting to and from work, shopping, dining out, and attending entertainment activities. Thus, the traditionally lower per-capita energy use of rural areas relative to urban areas is not reflected in Greene County, because, although most of the land area is rural, most of the population and the existing and proposed development is urban and suburban.

As discussed in Section II-L, future subdivision growth in Greene County will likely be steered to the immediate vicinity of Springfield. If this indeed holds true, it will yield an energy-efficient pattern of residential development.

L. LAND USE

1. Existing Land Use

The land-use distribution for the planning area and the distribution for the immediate Springfield vicinity are given in Tables 24

TABLE 23
ELECTRICITY AND GAS USE
SPRINGFIELD WASTEWATER TREATMENT FACILITIES
1979

Facility	Electricity (kilowatt-hours)	Gas (hundreds of cubic meters)	
Southwest Plant	22,870,000	849	(30,000 cu ft)
Northwest Plant	1,758,800	869	(30,700 cu ft)
Southeast Lift Station	487,200	-	
Cinnamon Square Lift Station	21,876	-	
Compton Hills Lift Station	21,336	-	
Arrowhead Lift Station	6,434	-	

Source: (195)

TABLE 24
LAND USE DISTRIBUTION
PLANNING AREA
1978[a]

Land Use	Acres	% of Developed Land	% of Total Area
Developed Land			
Residential	19,240	33.9	4.3
Commercial	2,810	5.0	0.6
Industrial	3,260	5.7	0.7
Public & Semi-public	6,840	12.0	1.5
Transportation	24,615	43.4	5.4
Subtotal	56,765	100.0	12.5
Undeveloped Land[b]			
Agricultural	245,545		54.3
Vacant	146,145		32.3
Water	3,870		0.9
Subtotal	395,560		87.5
TOTAL	452,325		100.0

(a) Outlying unincorporated area and small towns based on 1978 data. Springfield area based on 1976 data (see text).

(b) Agricultural land and surface water in or near Springfield is tabulated as "Vacant". Therefore, figures for agricultural, vacant, and water categories are approximations only. The subtotal of undeveloped land is accurate.

Source: (196, 197)

and 25, respectively. The immediate Springfield vicinity is defined in the 1976 Springfield Traffic Zone Study as the City itself plus a ring of land about two to three miles wide around it, including Battlefield, Brookline, part of Willard, and unincorporated areas. General locations of the major land uses are shown in Figure 26 (196, 197, 198).

a. Developed Land. There are approximately 57,000 developed acres in the planning area accounting for just over 12 percent of the total land area. Development is concentrated around Springfield with over 44,000 developed acres (78 percent) located in the Springfield vicinity.

Most of this developed area is residential. Nearly all development in southern Springfield and to the south and east of Springfield is residential. Commercial uses are located along major arterial streets and industrial development is distributed along major highway and rail routes.

Much of the development outside of the Springfield vicinity is residential. It is fairly scattered, with the number of subdivisions decreasing as the distance from Springfield increases. In addition, scattered industrial and commercial uses occur on a very small scale.

Transportation land uses, including roads, railways, and rights-of-way, represent the largest category of developed land use (about 43 percent of the developed land within the planning area and over a third of the developed land in the Springfield vicinity). The planning area is served by an adequate system of road networks, capable of handling current and future traffic volumes. Several improvements have been recommended but, due to funding limitations, may not be realized in the near future.

Even though most of the planning area's developed land is in the immediate Springfield vicinity, nearly 70 percent of the total land in that vicinity remains undeveloped. There is thus considerable vacant or agricultural land for future development within or near Springfield.

b. Agricultural Land. Over half of the land in the planning area, or 246,000 out of 452,000 total acres, is devoted to agricultural uses. The primary agricultural activity, both in terms of acres and total value, is livestock raising, and trends in agricultural production

TABLE 25
LAND USE DISTRIBUTION SPRINGFIELD VICINITY[a]
1976

Land Use	Acres	% of Developed Area	% of Total Area
Developed Land			
Residential	15,510	35.0	10.9
Commercial	4,505	10.2	3.2
Industrial	3,080	6.9	2.2
Public & Semi-public	5,020	11.3	3.5
Transportation	15,890	35.8	11.2
Mixed Uses	355	0.8	0.3
Subtotal Developed Land	44,360	100.0	31.3
Undeveloped Land[b]	97,400		68.7
TOTAL	141,760		100.0

[a] See text for definition.

[b] Water, vacant land, and agriculture uses.

Source: (197)

are indicated by Table 26. Because the soils in the planning area are relatively poor in comparison to the soils in northern Missouri, cultivation of grain crops is less important.

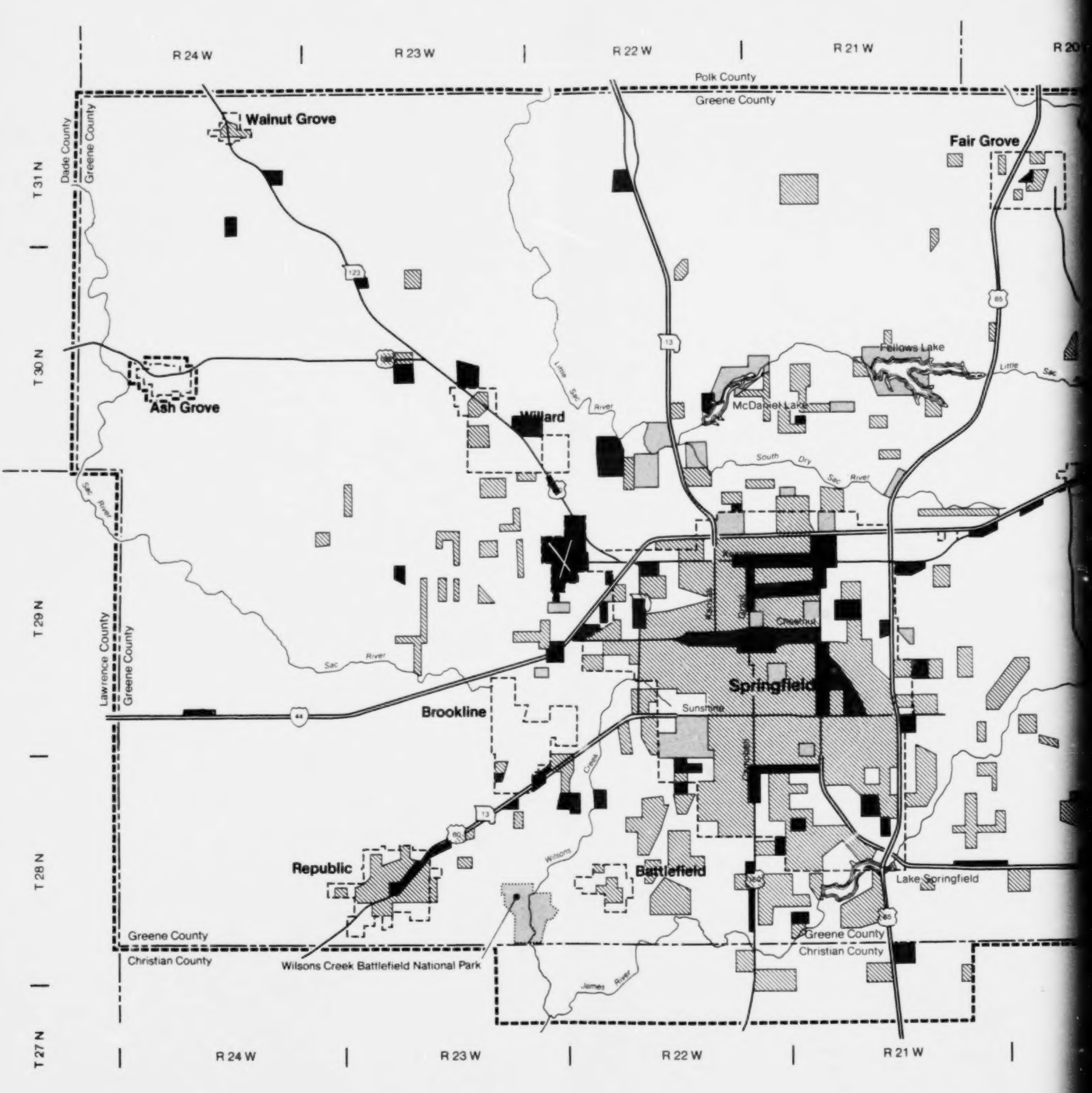
Agricultural lands are obviously valuable for food production. Such lands are also environmentally important because they reduce runoff and replenish ground water supplies by absorbing precipitation and because they provide buffer zones between environmentally sensitive areas and urban development.

The primary and secondary impacts of project alternatives on agricultural lands must be examined and considered during the decision-making process. EPA's official policy on funding of sewerage facilities states: "Consistent with Agency cost-effectiveness guidelines, interceptors and collection systems should be located on agricultural land only if necessary to eliminate existing discharges and serve existing habitation" (200).

2. Land-Use Controls

Increases in population and economic opportunities continually exert pressure for residential, commercial, and industrial development of land. Methods to control land use, principally comprehensive planning and zoning, have been implemented in many American communities in order to provide for orderly development. Comprehensive planning defines flexible goals and guidelines which are used to direct a community's long-range development. Zoning is more specific, delineating actual boundaries for certain types of land uses. A comprehensive plan is required for entities which utilize zoning, although the contents of the comprehensive plan are not specified by law. When implemented successfully, these tools can assist a growing community to achieve harmonious, efficient, aesthetically pleasing, and environmentally sound management of the various land uses.

Greene County and the City of Springfield both have comprehensive plans, zoning regulations, and subdivision regulations. Of relevance to this EIS is the Greene County Planning Commission's goal to provide the county with alternatives to or improved management and control of traditional septic tank treatment of sewage.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Ash Grove
Willard
Little Sac River
13
65
Fellows Lake
Little Sac
McDaniel Lake
South Dry Sac River
Sac River
Lawrence County
Greene County
Chestnut
Springfield
Brookline
44
Sunshine
Wilsons Creek
13
60
Republic
Battlefield
160
Lake Springfield
65
Greene County
Christian County
Greene County
Christian County
Wilsons Creek Battlefield National Park
James River
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Present Land Use

Figure 26

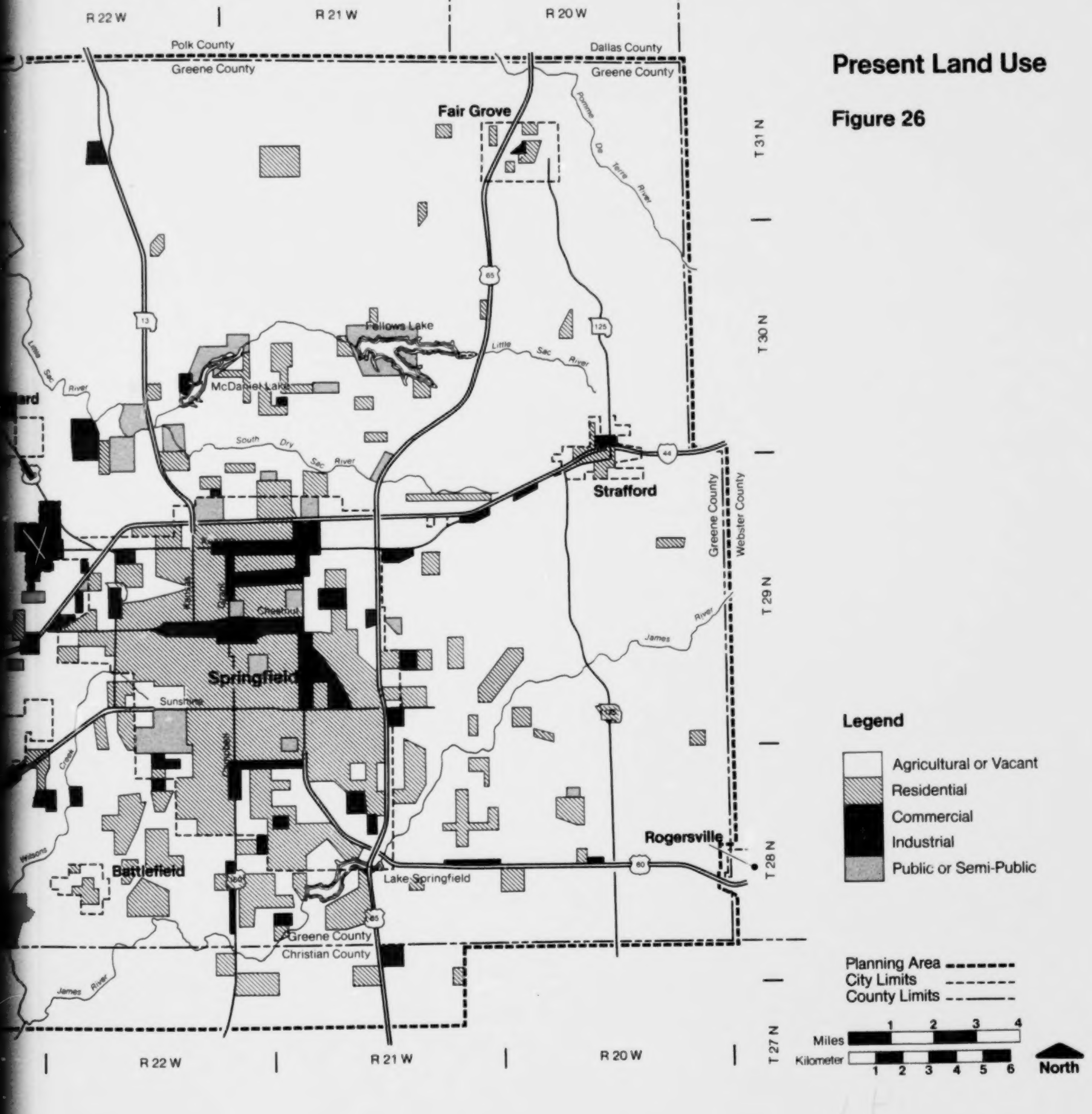

TABLE 26
AGRICULTURAL LAND USE
GREENE COUNTY
1975-1978

Crop	Harvested Area (acres)			
	1975	1976	1977	1978
Hay	57,525	54,720	53,324	58,921
Wheat	2,805	4,707	3,595	2,397
Corn	2,298	2,199	1,396	2,199
Grain Sorghum	1,100	704	704	902
Soybeans	605	655	704	1,396

Livestock on Farms	Total Number			
	1975	1976	1977	1978
All Cattle	116,000	107,000	102,000	81,500
Milk Cows	9,200	9,000	10,000	8,700
All Hogs and Pigs	8,400	10,800	8,000	6,900

Source: (199)

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Planned residential zoning in unincorporated parts of Greene County is to be restricted to an area within several miles of the Springfield city limits. Commercial zoning would be along major highways, and generally within the confines of residentially zoned areas; the only exceptions would be a strip along Missouri Highway 13 between Brookline and Republic and two interchanges along I-44 west of Springfield. Industrial zoning in the county would be limited to areas adjacent to the City of Springfield's industrially zoned areas, the major ones being along I-44 east and west of Springfield. The balance of the county would be zoned as an agricultural district. The concept of clustering future development around Springfield, through zoning, is based upon trunk sewers (and other services and utilities) being available in the areas adjacent to Springfield and development being guided to these areas (201, 202).

M. SOLID WASTE

Sources of solid wastes in Greene County include commerce, industry, residences, agriculture, and municipalities, including treatment plants. These wastes are produced in great quantities and contain a wide variety of materials. Their eventual disposal affects many segments of the community. For example, a properly constructed solid waste landfill may eventually be made into a park, while an improperly constructed one may leach harmful substances into ground and surface waters.

The Missouri Solid Waste Management Act of 1972 (as amended) requires solid waste facilities to obtain permits and meet standards set by the MDNR. The purpose of this act is to ensure that the disposal of solid waste does not endanger the environment or human health (205).

1. Nonhazardous

a. Municipal.

1) Refuse. As defined here, refuse comprises common municipal solid wastes, such as food wastes, rubbish, ashes and residues, and construction wastes.

a) Past Landfills. Refuse in Greene County has been buried in area landfills since before 1960. There are four abandoned refuse landfills in Greene County. These are shown in Figure 27 and Table 27. The two oldest are located in downtown Springfield, one adjacent to Jordan Creek and the other next to Wilsons Creek. The Bennett Street landfill is located on the site of the City's old wastewater treatment plant. Two abandoned sites, the Fulbright and Murray landfills, are located in the floodplain of the Little Sac River, north of Springfield.

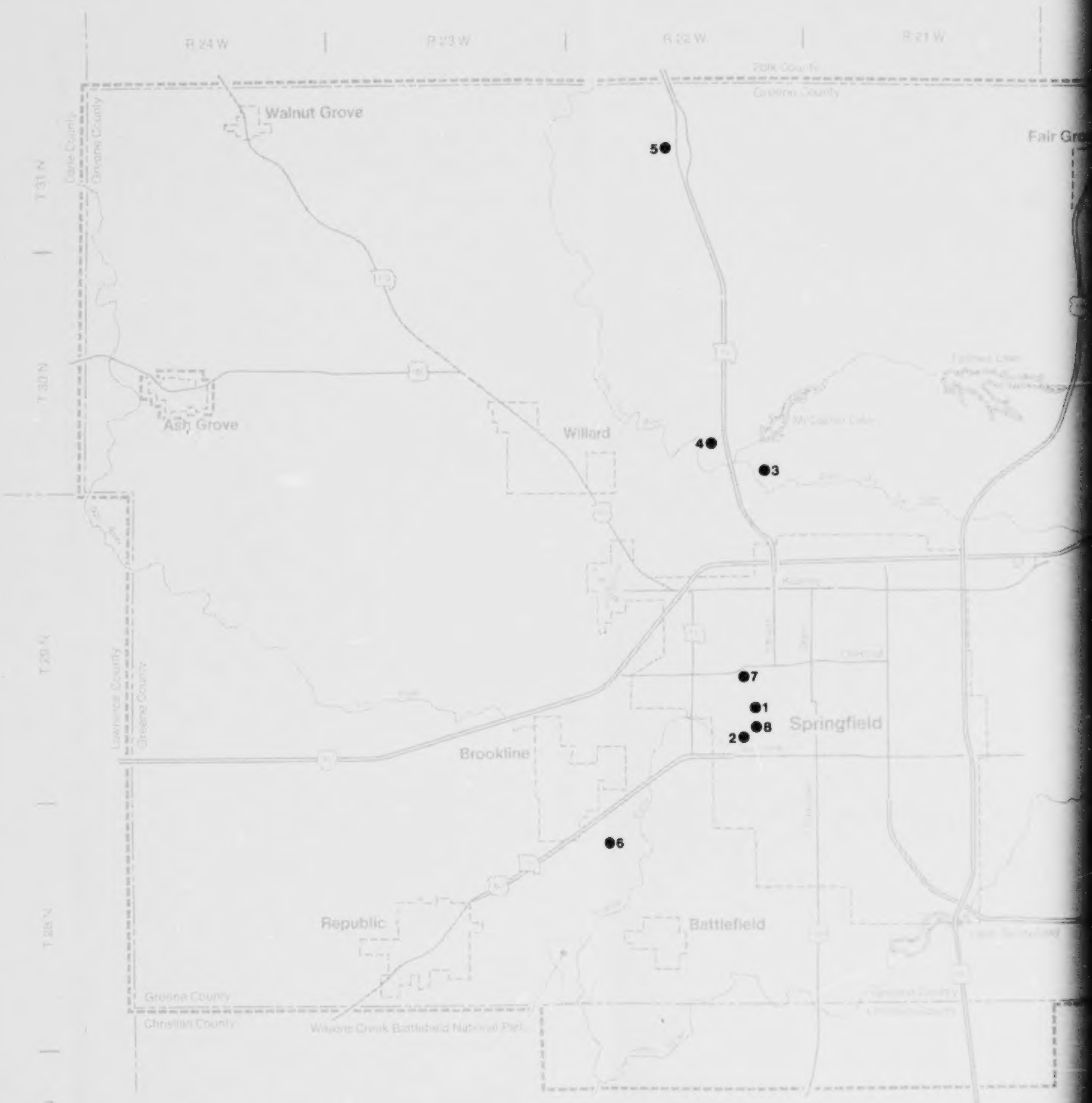
Springfield's abandoned landfills have become sources of water pollution because of improper design and construction. All of these landfills were established in floodplains, and are thus subject to occasional inundation (77). In addition, the thin, permeable, cherty clay soils and numerous springs and sink holes make this area one of the poorest in the state for landfill siting from the standpoint of potential groundwater pollution (208, 209). The two landfills in downtown Springfield were the most poorly designed since they were built with insufficient fill, and at sites too close to the adjacent streams (206).

Visible seepage has been detected at all of the abandoned landfill sites (206), as evidenced by the presence of black water and landfill debris in the immediate area (206, 210). In a 1976 study, slightly elevated heavy metal concentrations were detected near the Fulbright landfill and the Bennett Street landfill (206). In addition to heavy metals, other hazardous wastes have been discovered in the Fulbright and Murray landfills. Landfill leachate effects are being considered in the 1982-83 wasteload allocation study of the Little Sac River. Sampling of the Murray and Fulbright sites indicates significant oxygen demanding pollutants; cyanide was found at levels possibly toxic to aquatic life and two organic priority pollutants were also detected (66). Springfield has agreed to additional grading and cover work to help mitigate the problems.

b) Present Landfills. Refuse in the Greene County area is presently hauled by private firms to one of two transfer stations licensed by the MDNR. These are located on Olive Street and on Bennett Street. Private haulers transport the refuse from these stations to the Noble Hill landfill, which is licensed by the MDNR.

TABLE 27
REFUSE LANDFILLS AND TRANSFER STATIONS
GREENE COUNTY

Name	Dates of Use
Municipal landfill (unnamed)	Prior to 1960
Bennett Street Municipal Landfill	1960 - 1965
Fulbright Municipal Landfill	1965 - 1968
Murray Municipal Landfill	1968 - 1974
Noble Hill Municipal Landfill	1974 - Present
Southwest Power Station Industrial Landfill	1977 - Present
Olive Street Municipal Transfer Station	1972 - Present
Bennett Street Municipal Transfer Station	1976 - Present


R 24 W
R 23 W
R 22 W
R 21 W
Polk County
Greene County
Walnut Grove
Fair Gr
T 31 N
Dade County
Greene County
T 30 N
Ash Grove
Willard
McDaniel Lake
Fellows Lake
T 29 N
Lawrence County
Greene County
Kearney
Division
Springfield
Brookline
T 28 N
Republic
Battlefield
Lake Springfield
Greene County
Christian County
Wilsons Creek Battlefield National Park
T 27 N
1
2
3
4
5
6
7
8

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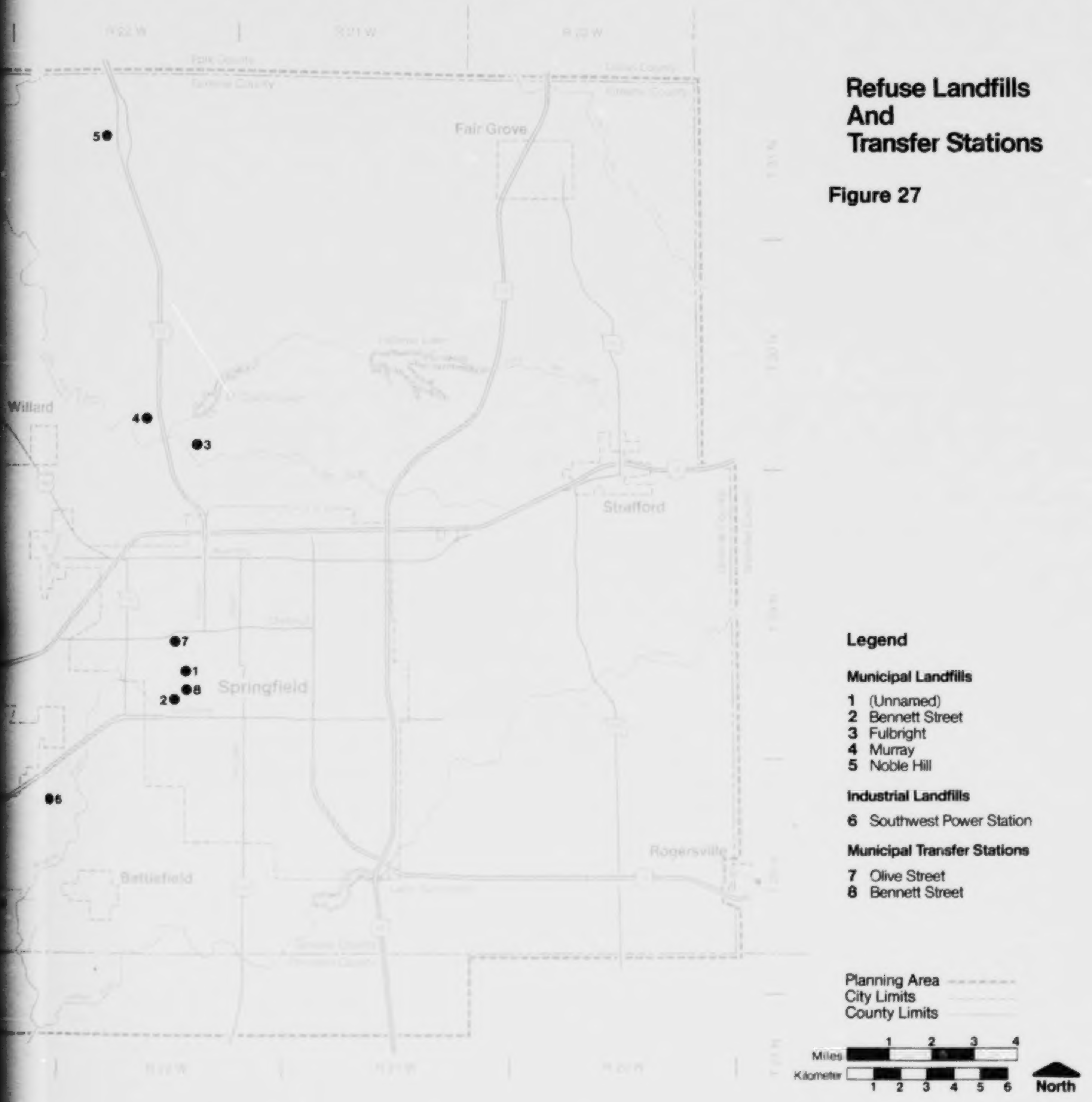
Refuse Landfills And Transfer Stations

Figure 27



The Noble Hill landfill, in operation since 1974, is located 10 miles north of Springfield, west of Missouri Highway 13 and about one-half mile south of Missouri Highway BB. It was originally designed to receive 500 metric tons per day, and to remain in use until 1984 (211).

The Noble Hill landfill was designed to avoid the seepage problems encountered at Springfield's former landfills. It was located in an area underlain by the Northview shale, which is relatively impermeable to water movement. In addition, the landfill was established on an escarpment well above the floodplain to avoid innundation (211).

Polluted leachate has been detected near Springfield's Noble Hill landfill, despite its improved design and operation. The leachate is making its way to the surface through a spring which was discovered near the landfill after excavation had begun. Corrective actions are being taken to prevent degradation of area streams by the seepage. These actions include refilling the area of the landfill near the spring with clay, and collecting and treating the seepage (210).

c) Future Landfills. Springfield's Noble Hill landfill is now expected to remain in use until the late 1980's, based on an assumed annual growth rate of 3 percent (212). Given the geologic conditions in the Springfield area and the pollution problems caused by the city's past landfills, the search for an acceptable future site will likely prove to be difficult (212).

To prevent a future shortage of acceptable landfill sites, the City of Springfield contracted with Mustang RDF Company to study the feasibility of a resource recovery system for Springfield's refuse. Phase I of Mustang RDF's study was completed in August 1980. It concluded that a resource recovery system is justified by the amount of waste generated in the area. This system would include recovery of aluminum, ferrous metal, and energy. Following removal of valuable metals, the waste would either be burned to produce steam or converted into refuse-derived fuel (RDF). Either the steam or RDF would then be sold to industries (212). The next phase of Mustang RDF's study consisted of more detailed examination of possible resource recovery systems. No action has been taken on implementation.

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2) Sludge. Wastewater sludge is the accumulated solids remaining after treatment. Sludge generally contains large volumes of liquid when produced; it may subsequently be dewatered and dried. Most American treatment plants dispose of sludge by landfilling. Because of its organic nature, it may also be applied to farm land as a soil conditioner.

Wastewater sludges are produced in large quantities at Springfield's Northwest and Southwest treatment plants. These sludges are municipal in nature, reflecting the sources of the wastewaters. Sludges from Springfield's Southwest plant do not contain excessive concentrations of heavy metals (213), except for occasional elevated cadmium concentrations (214), and are good sources of plant nutrients (213). Metals and other toxics in sludges from the Southwest Plant are within the guideline limits of the MDNR (1). Results of recent analyses of sludge from the Northwest Plant should be available soon.

Digested sludges from Springfield's two municipal wastewater treatment plants are generally applied as liquid or as dewatered cake to nearby farmers' fields or hay and pasture land owned by the City. During the fall and spring, however, the fields are often too wet to accept the liquid sludges, and the sludges are mechanically dewatered at the Southwest Plant before application to the fields (214). Sludge drying beds for a few days volume are also available at the Southwest Plant. Occassional odor problems and complaints have resulted from the land application of sludge from the Southwest Plant.

The land application sites have been monitored for heavy metals to signal any adverse impact on the soil, water, or plants. Heavy metals have not been shown to accumulate either in the ground water or in the plants grown on the sites. Some enrichment of cadmium, nickel, zinc, and lead in the surface soil has been indicated, however (213).

b. Industrial. The only permitted industrial landfill in Greene County is owned and operated by the Southwest Power Station. The landfill is located on the Company's property, west of Springfield (See Figure 27). It receives fly ash and bottom ash (210).

2. Hazardous Wastes

Hazardous wastes are defined by the MDNR as "any waste or combination of wastes which..., because of its quantity, concentration, or physical, chemical or infectious characteristics may cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness, or pose a present or potential threat to the health of humans or the environment" (44). They are regulated by the Hazardous Waste Management Commission, which was created by Missouri's Hazardous Waste Management Law, and by the Environmental Protection Agency under authority from the Resource Conservation and Recovery Act (RCRA). The MDNR administers and enforces the rules, standards, and regulations set by the Hazardous Waste Management Commission. Amendments to broaden the Commission's powers and strengthen the law were recently passed (215). After some revisions were made in Missouri's hazardous waste management statutes, EPA granted interim authority for partial management of hazardous waste generating, transporting, treating, storing, and disposal facilities in Missouri. The state will be seeking total authorization (from EPA) for hazardous waste management in Missouri.

There are no present, nor presently projected, permitted hazardous waste disposal sites in Greene County (210). The area's cavernous bedrock and numerous groundwater-surface water connections make the task of properly isolating a landfill from the environment essentially impossible. Hazardous wastes generated at an estimated 45 sources in Greene County are disposed of outside the planning area (216).

There have been some hazardous waste disposal activities undertaken without a permit in the planning area vicinity. Hazardous wastes, including spent acids and cyanide, were illegally dumped at the Fulbright and Murray landfills (84, 210). Also, dioxin-containing waste and contaminated soils have been found in the area of Aurora and Verona, which are in Lawrence County about 30 miles southwest of Springfield (217, 218). These hazardous waste problems are presently being extensively studied (210).

III. SPECIFIC SUBAREA ALTERNATIVES

Specific alternatives for each of the subareas were developed and evaluated as discussed in the Draft Wastewater Facilities Plan for Greene County Sewer District (1). This section briefly describes these alternatives, including regionalized alternatives, and indicates the specific alternative recommended on the basis of engineering criteria and costs. New information and changes since the draft Facilities Plan are noted. Capital and annual costs of each alternative are presented when available.

A. SPRINGFIELD SUBAREA

The Springfield subarea* includes the area served by Springfield's existing collection system, existing or planned trunk sewer drainage basins, and other significantly developed areas surrounding Springfield. Wastewater in the Springfield subarea is presently handled by: 1) collection and treatment by the City of Springfield system, 2) private systems serving subdivisions, trailer parks, shopping centers, and schools, and 3) individual on-site systems. Approximate numbers of persons currently served by these methods are:

Springfield Municipal System	115,000
Private Facilities	5,000
On-Site Systems (Septic Tanks)	40,000

The Springfield Municipal system serves some unincorporated growth areas adjacent to it in addition to the City itself. The Springfield subarea is separated by a major drainage divide into northern and southern portions, served by the Northwest and Southwest treatment plants, respectively (see Figure 28).

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* The Springfield subarea as delineated by the MDNR includes the cities of Springfield, Strafford, Brookline, and Battlefield and a large unincorporated area surrounding Springfield. Strafford, Brookline, and Battlefield are addressed as individual subareas for facilities planning purposes, with alternatives that include possible regionalization.

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For wastewater facilities planning, population projections were disaggregated according to major system components and drainage areas. Projections of industrial, commercial, and institutional expansion and locations were also made. Future flow and wastewater loadings were then projected and broken down by segments: 1) domestic, 2) industrial, 3) institutional, 4) commercial, and 5) allowable infiltration/inflow. The effects of future flows and waste loads on system facilities and areas were analyzed.

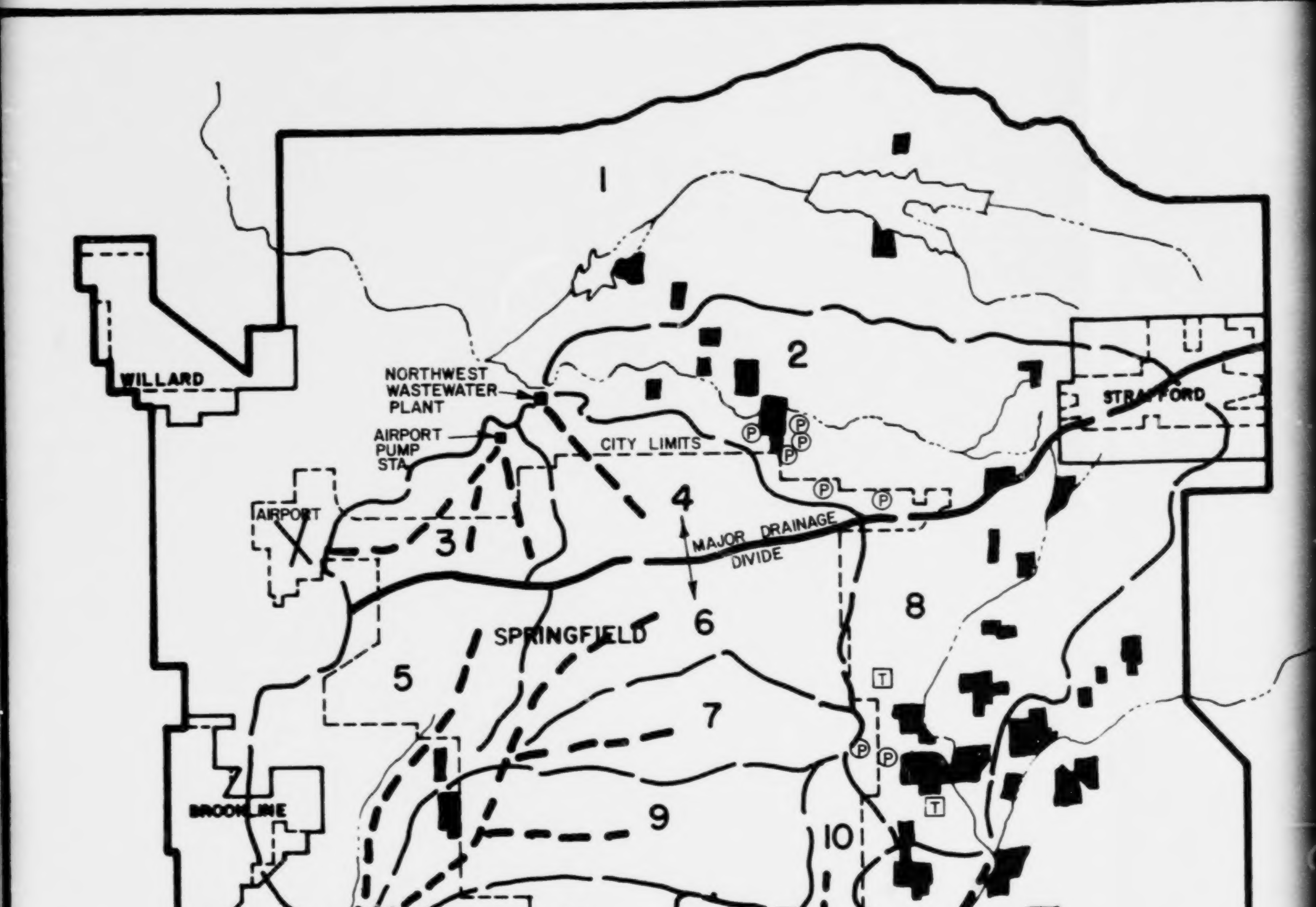
A summary of the additional population projected for the Springfield subarea plus existing population not served is as follows:

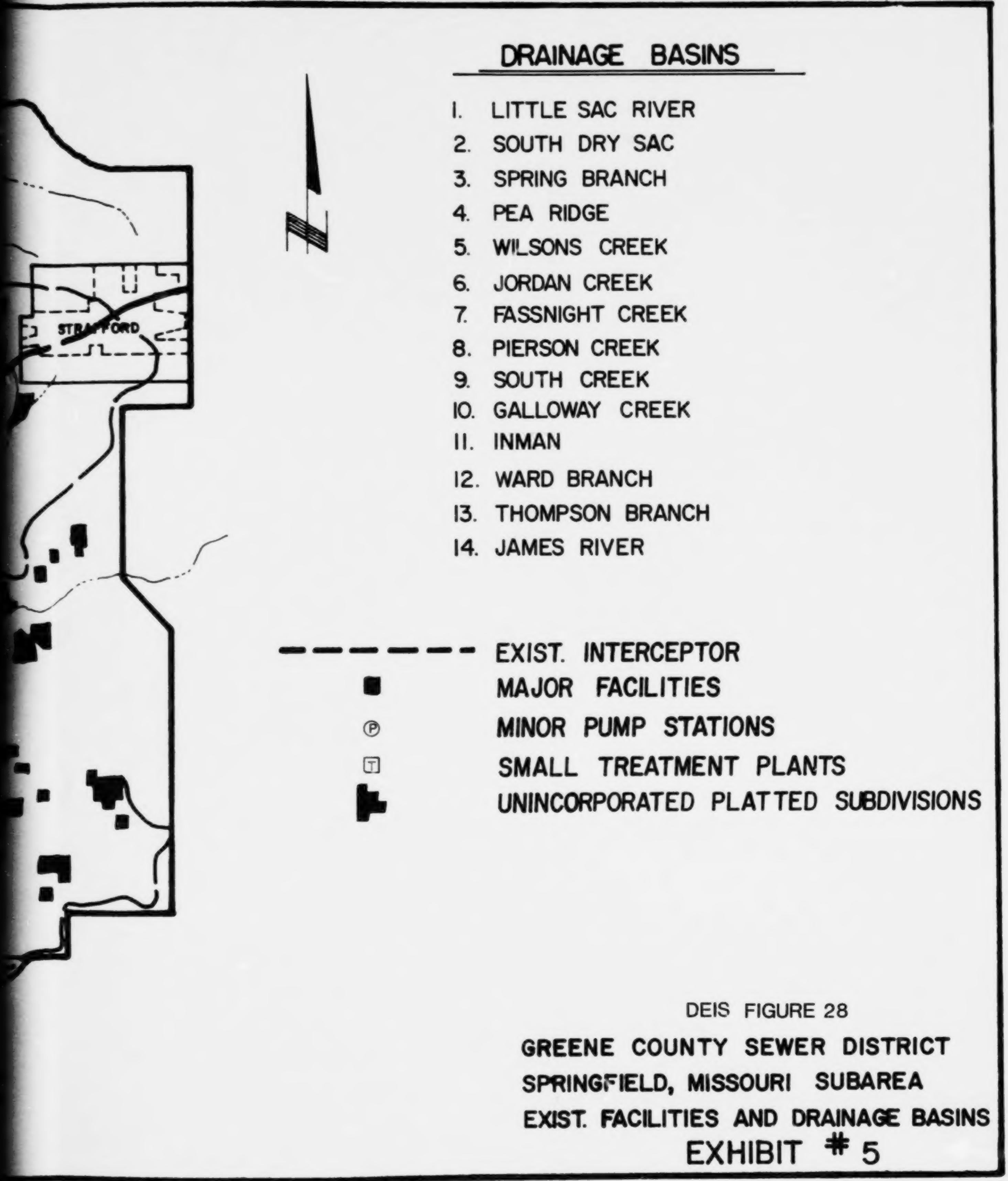
City of Springfield	
Existing Population Not Served	19,400
Additional Population by Year 2005	35,400
Additional Population to be Served	54,800
Unincorporated Area	
Existing Population Not Served	16,540
Additional Population by Year 2005	39,200
Additional Population to be Served	55,740

The major new facilities proposed for the Springfield subarea include: the Pierson Creek and Thompson Branch interceptors of the southern system; and the new Northwest treatment plant and Little Sac and South Dry Sac interceptors of the northern system. Additional information concerning the southern and northern systems and proposed facilities and alternatives is presented below (see Figure 29).

1. Southern System

The southern portion of the Springfield Municipal system handles about 85 percent of all residential customers served in the city, plus most of the industrial and commercial areas. As shown in Figures 28 and 29 and Table 28, systems of existing or planned trunk sewers, interceptor sewers, and pump stations deliver wastewater to the Southwest Plant.


WILLARD
1
NORTHWEST WASTEWATER PLANT
2
STRAFFORD
AIRPORT PUMP STA
CITY LIMITS
AIRPORT
3
4
MAJOR DRAINAGE DIVIDE
SPRINGFIELD
6
8
5
7
BROOKLINE
9
10
11
SOUTHWEST WASTEWATER TREATMENT PLANT
GALLOWAY PUMP STA.
13
12
14
BATTLEFIELD
GREENE CO.
CHRISTIAN CO.
JAMES RIVER PUMP STATION



DRAINAGE BASINS

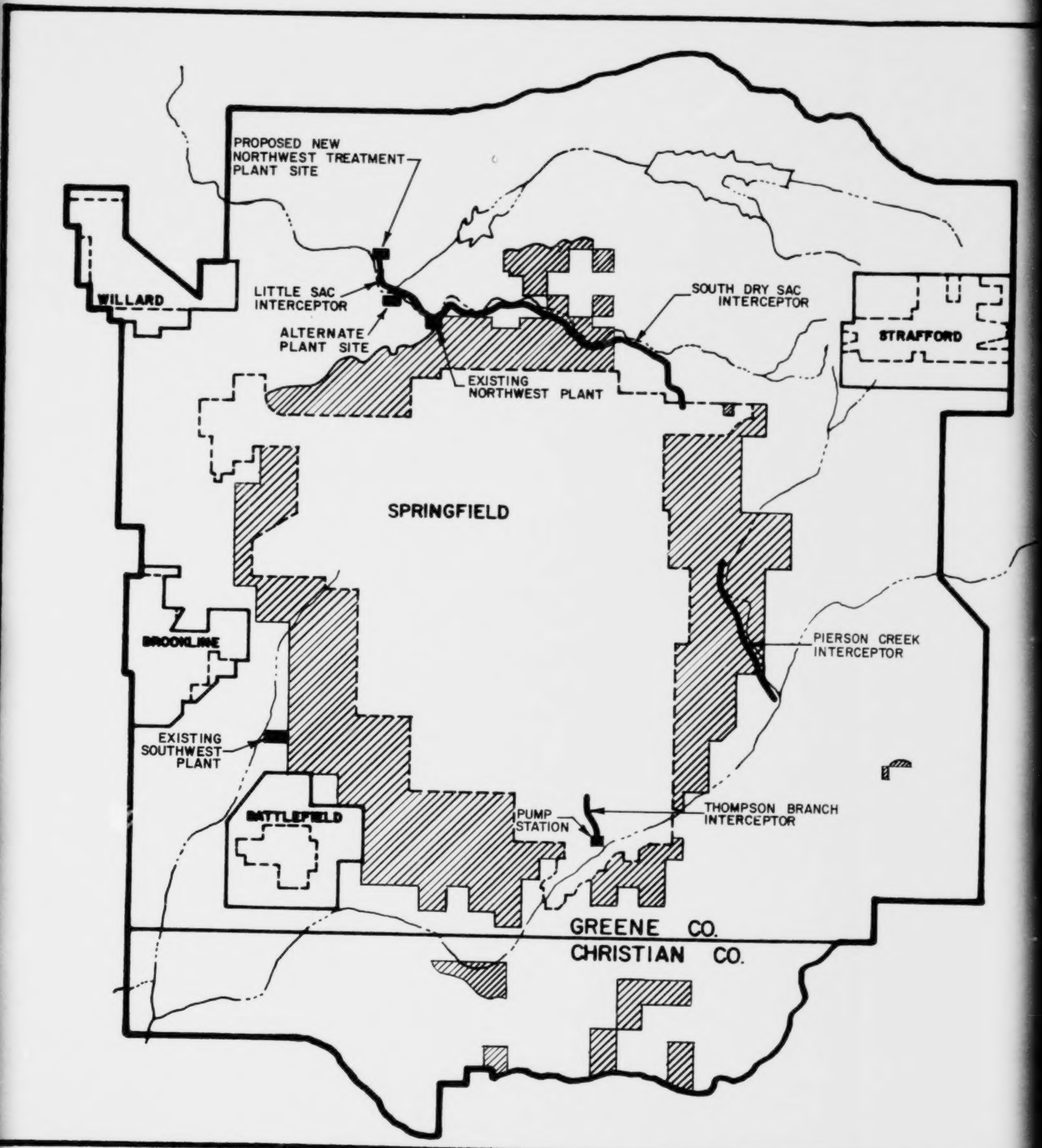
1. LITTLE SAC RIVER
2. SOUTH DRY SAC
3. SPRING BRANCH
4. PEA RIDGE
5. WILSONS CREEK
6. JORDAN CREEK
7. FASSNIGHT CREEK
8. PIERSON CREEK
9. SOUTH CREEK
10. GALLOWAY CREEK
11. INMAN
12. WARD BRANCH
13. THOMPSON BRANCH
14. JAMES RIVER

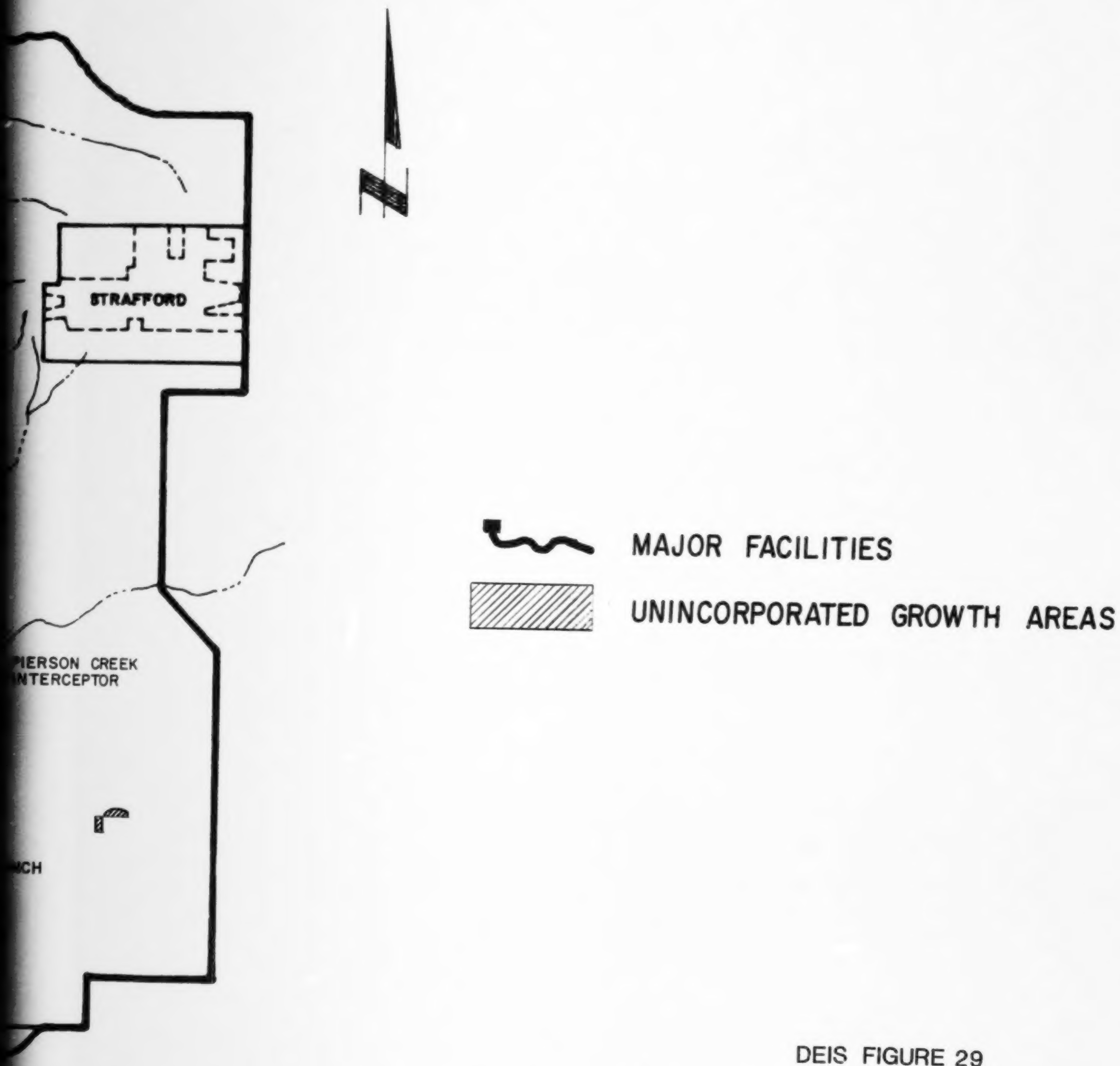
— — — — — —	EXIST. INTERCEPTOR
■	MAJOR FACILITIES
Ⓟ	MINOR PUMP STATIONS
⊡	SMALL TREATMENT PLANTS
▙	UNINCORPORATED PLATTED SUBDIVISIONS

DEIS FIGURE 28

GREENE COUNTY SEWER DISTRICT
SPRINGFIELD, MISSOURI SUBAREA
EXIST. FACILITIES AND DRAINAGE BASINS

EXHIBIT # 5


PROPOSED NEW NORTHWEST TREATMENT PLANT SITE
WILLARD
LITTLE SAC INTERCEPTOR
ALTERNATE PLANT SITE
SOUTH DRY SAC INTERCEPTOR
EXISTING NORTHWEST PLANT
STRAFFORD
SPRINGFIELD
BROOKLINE
PIERSON CREEK INTERCEPTOR
EXISTING SOUTHWEST PLANT
BATTLEFIELD
PUMP STATION
THOMPSON BRANCH INTERCEPTOR
GREENE CO.
CHRISTIAN CO.



DEIS FIGURE 29

GREENE COUNTY SEWER DISTRICT
SPRINGFIELD, MISSOURI SUBAREA
PLANNED MAJOR FACILITIES AND
GROWTH AREAS

EXHIBIT # 10

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TABLE 28
CITY OF SPRINGFIELD
SOUTHERN SYSTEM
MAJOR SEWER CAPACITIES AND FLOWS

Facility	Size Dia.	Capacity(f)	Average Flow	Peak Flow	Design PE(a)
SOUTHWEST PLANT INTERCEPTOR SYSTEM					
Southwest Plant Interceptor (at SW plant)	60"	70.0 MGD	22.4 MGD	100 MGD (surcharged)	350,000
Southwest Plant Interceptor (at Scenic & South Creek)	60"	65.0 MGD	15.7 MGD	Surcharges	325,000
Inman Road Trunk (at SW Plant Interceptor)	30"	6.5 MGD	0.3 MGD	2.5 MGD	(65,000)(b) 32,500
Fassnight Creek Trunk (at SW Plant Interceptor)	36"	42.6 MGD	6.4 MGD	Surcharges	213,000
Upper Wilson Creek Trunk (at Fassnight Creek)	36"	9.6 MGD	1.4 MGD	Surcharges	48,000
South Creek Trunk (at SW Plant Interceptor)	42"	16.4 MGD	3.5 MGD	Surcharges	82,000(c)
Jordan Creek Trunk (at SW Plant Interceptor)	54"	28.0 MGD	14.3 MGD(d)	Surcharges	140,000
Wilson Creek Interceptor(e)	42"	12.5 MGD	0	0	62,500
JAMES RIVER PUMP STATION SEWER SYSTEM					
James River Interceptor(e) (at James River Pump Station)	48"	32.0 MGD	0	0	160,000
Ward Branch Trunk(e) (at James River Pump Station)	30"	8.0 MGD	0.1 MGD	0.2 MGD	40,000
Galloway Trunk	30"	12.6 MGD	Newly constructed		63,000
Pierson Creek Trunk	30"	8.8 MGD	To be constructed		44,000

(a) Based on 100 gpcd at 50% of sewer capacity, i.e., peaking factor of 2.
(b) Receives discharge from new James River Pump Station.
(c) Receives discharge from Half-a-Hill Pump Station.
(d) Includes flow from Fassnight Creek Trunk.
(e) Newly constructed, few or no connections.
(f) Capacity of sewers of equal size varies because of alignment, grade, and other factors.

Source: (1)

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The Southwest Plant interceptor and newly constructed Wilson Creek interceptor are the two major gravity sewers that discharge directly into the Southwest Plant. Several major interceptor and trunk sewers are tributary to the Southwest Plant interceptor.

The James River interceptor and pump station system serves or potentially serves large portions of the southern and eastern parts of the Springfield subarea. These areas have grown significantly since the early 1970's and are projected to continue to grow at a greater rate than other parts of the subarea. The recently completed Ward Branch and Galloway trunks and the planned Pierson Creek trunk are tributary to the James River interceptor. The James River pump station discharges to the Inman Road trunk of the Southwest Plant interceptor system.

The Galloway area is now served by the new Galloway trunk. Previously, this area was served by the Half-a-Hill pump station, which pumped to the Fassnight trunk system and the Southwest Plant. Excessive infiltration and inflow during wet weather resulted in overflow at the pumping station and discharge into Sequiota Creek and Lake Springfield. The Galloway trunk has eliminated the overflows.

Infiltration and inflow (I/I) to the Southwest Plant are excessive during periods of rainfall. Flows of up to 75 MGD exceed the 42-MGD hydraulic capacity and supplemental holding capacity of the plant. Infiltration and inflow for 7- and 14-day high flow periods were calculated to be 8600 and 7600 gallons/inch diameter/mile/day, which greatly exceeds the EPA guideline criteria of 2000 to 3000 gallons/inch diameter/mile/day (217). As indicated in Table 28, problems of surcharging trunk and interceptor sewers are also caused by excess I/I.

Needs and alternatives to handle future wasteloads were evaluated for the southern system. Collection and treatment alternatives and short range and long range improvements were considered. Areas of concern include I/I, treatment plant hydraulic and process capacities, sludge disposal, trunk and interceptor sewers, and possible effluent reuse.

a. Southern System Treatment. A summary of current and projected flow, BOD, and SS loadings to the Southwest Treatment Plant system and comparative design capacities of the existing plant are given in Table 29. Even during dry weather the current flow of 17.0 MGD includes over 3.5 MGD I/I. The year 2005 projected loadings are shown with James River pump station flows (case 1) and without (case 2). Alternatives for the Southwest Plant system consist of expansion and improvements with and without a new treatment plant for the James River system, the possibilities of effluent reuse or land application, and potential regionalization that might serve the Battlefield, Brookline, Republic and Strafford subareas. The regionalization alternatives are described in the sections on alternatives for each of these specific subareas.

1) Plant Improvements and Expansion.

a) Primary Treatment. The influent channels, grit removal system and primary clarifiers can handle peak flows of 42 MGD compared to a current average day peak flow of nearly 39 MGD. Whether or not the James River system remains tributary to the Southwest Plant, hydraulic expansion of these facilities will be needed before 2005.

b) Oxygenation System. Calculations indicate the oxygenation system can hydraulically handle flows 50 percent over current design and can handle BOD loadings as well as flow for the year 2005.

c) Secondary Clarifiers. Studies of settling velocities and overflow rates find that clarifier capacity is limited to the design peak flow of 42 MGD. When mixed liquor suspended solids in the oxygenation system are high, capacity is sometimes more limited. If the James River system flows to the Southwest Plant continue after 1992, construction of additional clarifiers will be necessary. If not, the existing units will be satisfactory until 2005.

d) Nitrification System and Final Clarifiers. The nitrification system consists of the aeration tanks and clarifiers of the original plant and three added clarifiers. This portion of the plant has less reserve capacity than many others, and is limited hydraulically to 42 MGD peak flow, or less if conditions are not favorable for nitrification. If James River system flows remain tributary after 1992, expansion of these facilities will be required.

TABLE 29
SOUTHWEST SYSTEM
CURRENT AND PROJECTED WASTE LOADINGS

Parameter	Existing Plant Design	Current	Projected-2005* Case 1	Projected-2005* Case 2
Flow (MGD)				
- Average Day	30	25.4	35.7	30.3
- Peak Hydraulic	45	--	--	--
- Dry Weather	--	17.0	26.8	21.7
- Peak Day	--	74.7	86.2	79.9
- Peak Rate	--	100	115	109
- Peak Flow on Average Day	--	38.7	53.7	46.0
BOD (lb/day)				
- Average Day	92,600	44,400	80,655	68,755
Susp. Solids (lb/day)				
- Average Day	50,000	35,300	63,200	49,625

*Case 1 includes the James River pump station flows while Case 2 does not.

e) Final Filters. At a flow of 42 MGD the eight multi-media gravity filters are loaded at 4.2 gpm/sq. ft. These units should handle peak flows of at least 60 MGD (6.0 gpm/sq. ft.) and should thus be adequate to the year 2005 with or without James River system flows.

f) Ozonation System. Ozone is applied at three parallel covered tanks with a flow capacity of 75 MGD. The system performs well except for equipment failures and during periods of excessive I/I when settled overflow is mixed with final effluent.

g) Flow Equalization and Overflow Facilities. When plant influent flow rate is greater than 42 MGD, wastewater is routed to a 4.4-MG settling pond which overflows to two holding ponds of 7.4 and 29.4 MG capacity, respectively. Retained flows are pumped back to the treatment plant when influent flow drops below 42 MGD. If the ponds are full, overflows are disinfected at the ozonation tanks and discharged. For the 1979 to mid 1982 periods, overflow quantities averaged 246 MG/year. Unless controlled, quantities of I/I and resultant overflows can be expected to increase with new sewer construction and existing collection system deterioration.

h) Sludge Management. The sources of sludge at the Southwest Plant are primary clarifier sludge and waste activated sludges from the oxygenation and nitrification systems. Solids in the effluent filtration system backwash, flotation thickener subnatant*, and vacuum filter filtrate are returned to the primary clarifiers. Primary sludge and thickened waste activated sludge are anaerobically digested and applied to farmland as liquid or dewatered cake.

The existing sludge treatment process is well designed, reliable, and energy efficient. The anaerobic digestion process is satisfactory with good gas production and volatile suspended solids (VSS) reduction. Odor problems from land spreading of the sludge are caused by the relatively high VSS content of the treated sludge and the application rates necessary on the available land.

*Subnatant is the relatively clear water below the concentrated, floating sludge.

The six existing air flotation thickeners for waste activated sludge were loaded at 9.4 lb/sq ft/day during 1981 compared to a maximum design loading of 44 lb/sq ft/day. Average loadings in the year 2005 would be 16 lb/sq ft/day and the existing thickeners are therefore more than adequate.

Two-stage sludge digestion is used. Two of the three existing anaerobic digesters serve as primary digesters and the third is the secondary unit. Digester gases are used to fuel a diesel-driven air blower for nitrification, boilers that heat the digesters, and boilers that heat the blower building and office. Analysis showed that using the existing system, VSS content of digested sludge would increase about two percent at the 2005 projected wasteload compared to 1981 actual performance; and also showed that the addition of a third primary digester would only improve VSS reduction by two percent. It was concluded that additional anaerobic digestion would not significantly reduce the potential odor problems from land spreading of the sludge.

In 1981, about 40% of the sludge was spread as a liquid and the rest as dewatered sludge cake with about 12 percent solids. The existing coil-type vacuum filters have a design solids loading of 59,700 lbs/day which is greater than the 2005 projected total of 44,600 lbs/day. While the vacuum filters have adequate capacity to handle future sludge quantities, chemical conditioning costs and limited sludge cake dryness are drawbacks.

Since 1960, sludge has been spread on about 1320 acres of area farmland and City owned land. Sludge is hauled to private land on request from the owner. Nearly all suitable soils within a five mile radius of the plant are now being used for sludge disposal. Potential problems will increase in the future with greater quantities and higher VSS content of digested sludge, reduced pathogenic organism kill with less digester detention time, and a reduced land availability from suburban development.

The demand for land application of sludges by area farmers is expected to remain about the same over the planning period. In order to control odors and assure pathogen kills, methods for further stabilizing the sludge were reviewed. The conventional methods available are lime stabilization, aerobic digestion, thermal conditioning, or composting. A new method, "oxyozosynthesis," also has some promise.

Lime stabilization is currently practiced when lime is added to help produce vacuum filter sludge cake. This controls odors temporarily, but after land spreading, odor problems develop since the sludges are generally not plowed into the ground. Providing an additional one to two weeks storage at high pH may improve lime stabilization effectiveness.

Oxyozosynthesis involves the application of oxygen and ozone at pH 5 and 60 psi pressure for 1½ to 2 hours. Reportedly, the sludge could then be thickened and dewatered to produce an odorless, bacteria-free cake. Since the Southwest Plant has a supply of oxygen and ozone plus flotation thickeners and vacuum filters for dewatering, the oxyozone reaction chamber and related equipment may be the only new equipment needed.

The use of aerobic digestion, composting, or thermal conditioning would require major changes and expenditures and would only be considered if further lime stabilization or oxyozosynthesis is not feasible or effective. The addition of further VSS reduction and sludge stabilization for land spreading appears more practical and less costly than a major change in disposal method such as landfilling or incineration. Alternate disposal methods should be considered and evaluated with overall solid waste handling and disposal. Further evaluation should be conducted in the next few years as Springfield's sanitary landfill is nearing capacity. For the short range, pilot or plant studies on oxyozosynthesis and lime stabilization should be conducted.

2) Effluent Reuse. The potential for reuse of treated effluent from the Southwest Treatment Plant exists with future expansion to City Utilities Southwest Power Plant, about 1/4 mile away. Power supply studies in 1979 and 1981 addressed the possibility of using effluent for cooling water on future generating units. Further treatment methods, including phosphate and nitrate removal, are discussed. Consideration should be given to the use of treated effluent when it is decided to construct a new generating unit.

3) Land Application. Land application of wastewater is not feasible or practical for the Springfield southern system since sufficient land areas are not available, soils and geology are unfavorable, costs would be unreasonable, and the decision and investment in treatment and discharge has already been made. Approximately 16,000 acres would be needed for irrigation and 1,500 acres for storage.

4) Short Range Needs. Needs within the next five years for the southern system include:

- Pilot studies of further sludge stabilization prior to land spreading.
- Incorporation of sludge treatment and disposal studies into overall solid waste management planning.
- A sewer system evaluation survey to locate areas of excessive I/I and determine the cost-effectiveness of removal or storage and treatment.

Preliminary cost estimates for these evaluations are $50,000 for the sludge pilot studies, $30,000 for sludge studies as part of solid wastes management, and $2,500,000 for the sewer system evaluation study.

5) Long Range Needs. Needs within the next five to ten years involve major decisions and significant improvements or additions if wasteloads increase as projected. The principal decision will be whether to expand the Southwest Plant to handle all southern system flow or to construct a new plant on the James River for treating James River system wastes. The exact needs and better cost comparisons can be determined nearer the time hydraulic capacities are reached but preliminary comparative total annual costs are $1,224,000 for expansion of the Southwest Plant and James River pump station system and $1,511,000 for construction of a new James River basin treatment plant (see Table 30).

The effluent criteria for discharge to the James River are assumed to be the same as for the Southwest Plant. Costs are based on a single stage oxygenation and nitrification process. The existing James River pump station would be used to pump to the new plant, located about one mile away.

TABLE 30
PRELIMINARY COSTS COMPARISON
OF JAMES RIVER SYSTEM ALTERNATIVES

Case 1 - Expand Southwest Plant and James River Pump Station

Plant Additions:	
Primary treatment	$ 300,000
Secondary clarification	1,300,000
Nitrification	3,100,000
Final clarification	1,400,000
Miscellaneous construction	500,000
Sub-total	$6,600,000
Pump Station and Force Main Additions:	
Pump station	$ 100,000
Force main extension to SW Plant interceptor	1,100,000
Miscellaneous construction	200,000
Sub-total	$1,400,000
Non-Construction Costs:	
Design	$ 438,000
Construction inspection and management, soils investigation, O&M manual, start-up, administrative and legal	420,000
Contingency	800,000
Sub-total	$1,658,000
Total Capital Cost	$9,658,000
Salvage Value Present Worth	460,000
Present Worth	$9,198,000
Equivalent Annual Cost	$ 894,000
Annual O&M Cost	330,000
Total Annual Cost	$1,224,000

Case 2 - New James River System Plant

New Treatment Plant	$7,100,000
Pump Station:	
Force main to plant	$ 400,000
Pump alterations	100,000
Miscellaneous construction	50,000
Sub-total	$ 550,000

TABLE 30 (continued)

Non-Construction Costs:	
Design	$ 421,000
Construction inspection and management, soils investigation, O&M manual, start-up, administrative and legal	465,000
Contingency	765,000
Sub-total	$1,651,000
Total Capital Cost	$9,301,000
Salvage Value Present Worth	440,000
Present Worth	$8,861,000
Equivalent Annual Cost	$ 861,000
Annual O&M Cost	650,000
Total Annual Cost	$1,511,000

b. Interceptor and Trunk Sewers. Land developability studies in conjunction with the population projections for the Springfield subarea showed that significant growth can be expected in parts of the unincorporated area tributary to Springfield's southern system (see Figure 23). These areas are tributary to the James River interceptor, Ward Branch trunk sewer, Wilson Creek interceptor, and planned Pierson Creek interceptor. Since most of the major trunk and interceptor sewer network is in place and designed as a gravity system, planning for new sewer needs is also based upon conventional gravity sewers. Sewers are sized for the year 2025 population projections rather than 2005 to minimize future environmental problems and costs associated with sewer construction in areas of karst geology, springs, losing streams, and shallow bedrock.

Sewers are considered only where existing development warrants, since much of the area is now sparsely populated. Specific needs for each major basin are now discussed, and categorized as short range (1 to 5 years), and long range (5 to 10 years). Sewers shown as short range needs will eliminate existing treatment facilities and pump stations or serve developed areas with existing "dead" sewers. Sewers shown as long range needs will serve existing unsewered developments.

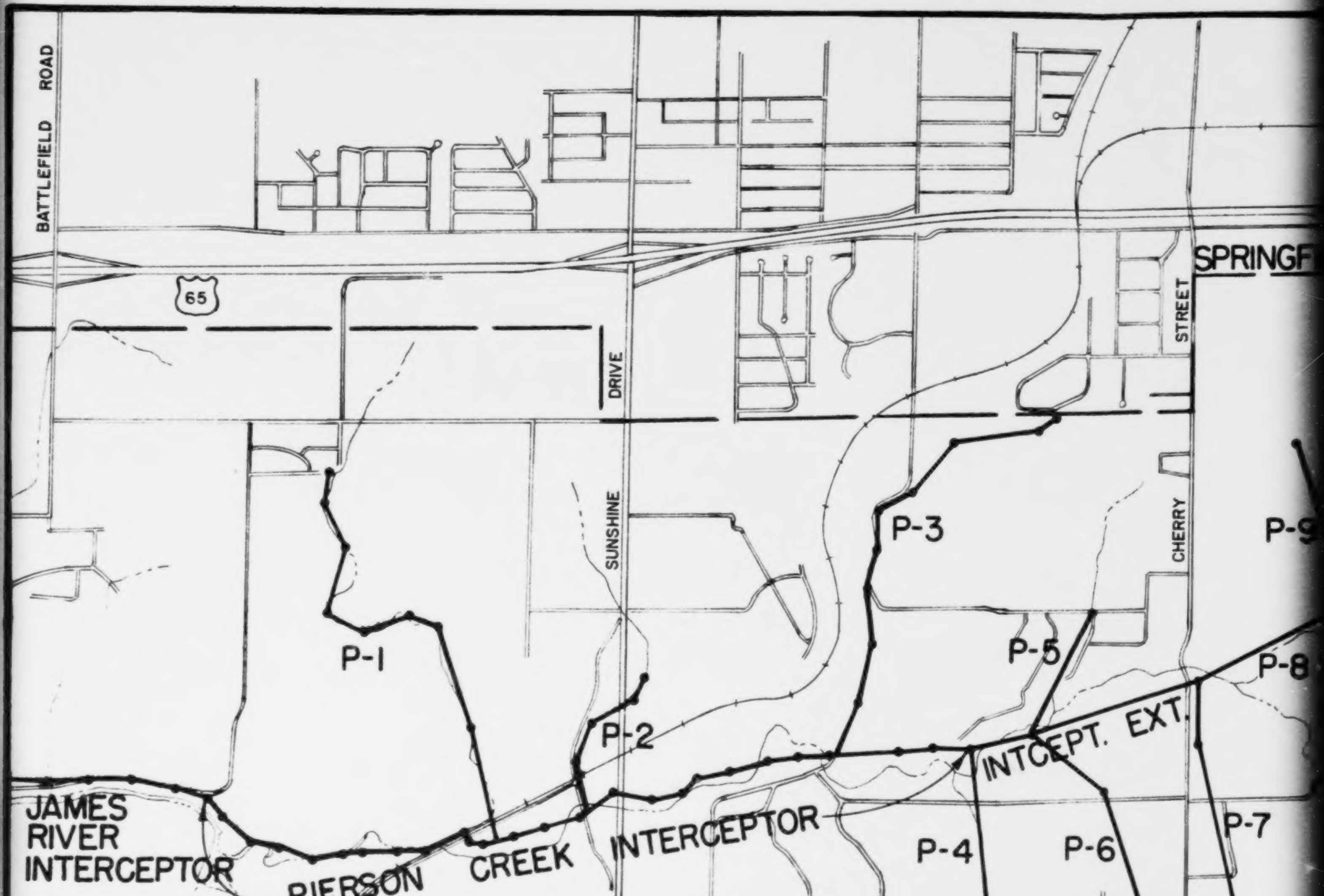
1) Pierson Creek Basin. Although the Pierson Creek interceptor has not been constructed, final design has been complete for some time. Construction has been awaiting funding. Tributary to the planned interceptor there are about 3,850 acres of unincorporated land in which significant growth is projected. There are also several large developments within the Springfield city limits, east of Highway 65. There are currently about 8,000 persons in Springfield and unincorporated areas in the basin, and average existing flow is estimated at 0.357 MGD. Projected average flow is 1.445 MGD in 2005 and 2.207 MGD in 2025.

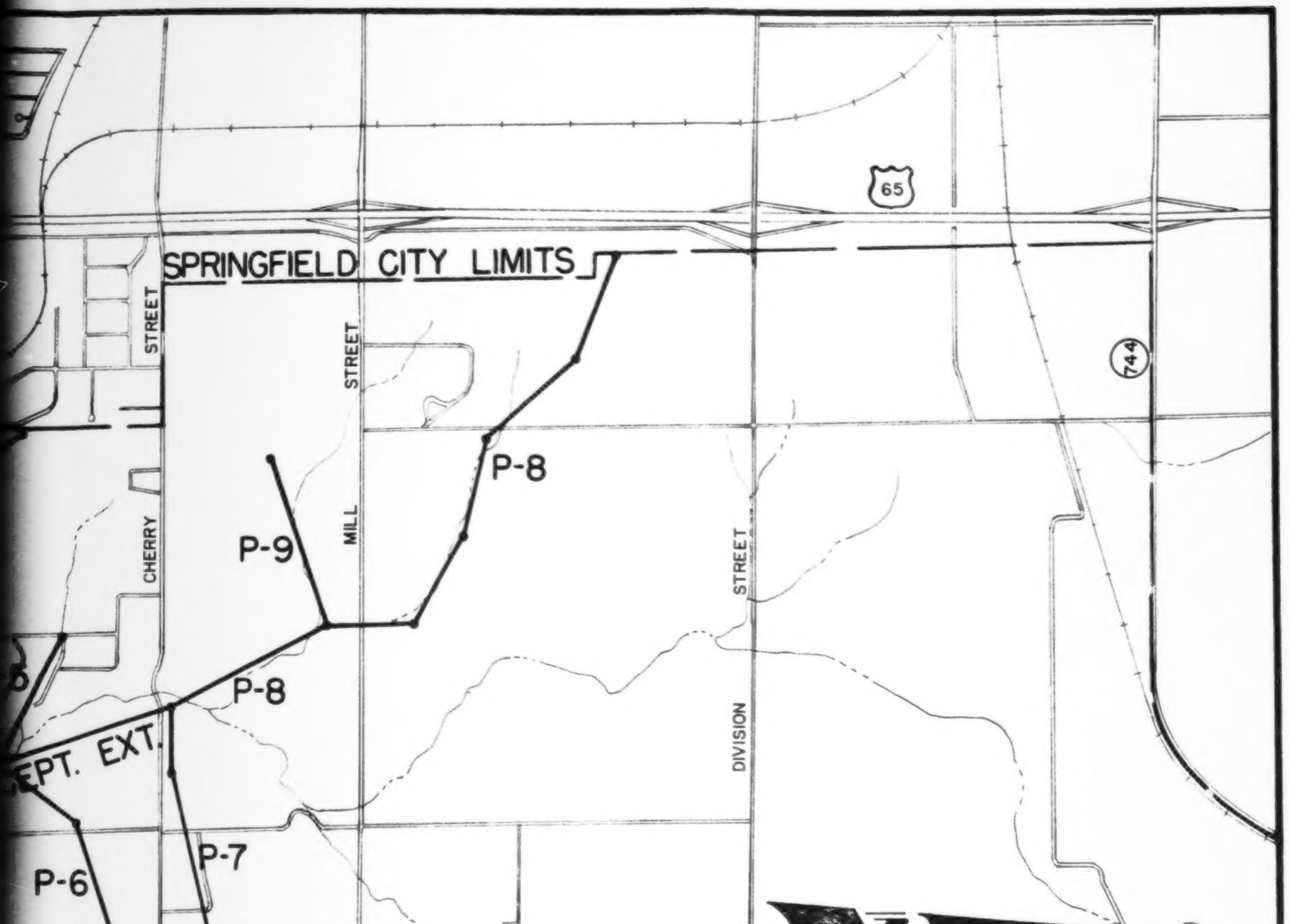
Short range needs include a 1,000 ft extension of the currently planned Pierson Creek interceptor plus lines P-2, P-3, and P-5 (see Figure 30). Line P-2 would eliminate the package treatment facility serving Chappel Hills Subdivision and provide service for part of Oak Knolls Subdivision where there are existing dead sewers. Line

P-3 would serve the large part of Oak Knolls subdivision and several developments within Springfield including Hickory Village, Hickory Hills Country Club District, and White Oak Subdivision. Line P-5 would connect to the dead sewers in Hickory Hills. A lagoon serving a smaller trailer park on Cherry Street could also be eliminated, and an interim pump station constructed to eliminate the Hickory Hills Country Club treatment facility. Costs are estimated as follow:

Pierson Creek Interceptor (as currently planned)	$1,500,000
Pierson Creek Interceptor Extension (1,000 L.F.-21" sewer)	54,250
Line P-2 (2,500 L.F.-10" sewer)	73,750
Line P-3 (3,000 L.F.-12" sewer) and 3,500 L.F.-18" sewer)	293,000
Line P-5 (2,000 L.F.-8" sewer)	44,000
Total Construction Cost	$1,965,000
Design	117,000
Construction inspection and management, soils investigation, easements, administrative and legal	232,500
Contingency	196,500
Total Project Cost	$2,511,000

Long range needs include further extension of the Pierson Creek interceptor to just north of Cherry Street and construction of lines P-1, P-4, P-6, P-7, P-8, P-9, and P-10. Line P-1 would serve Ridgeview Terrace Subdivision and Country Club Village Heights which are unsewered. Lines P-4, P-6, and P-7 would serve Cedar Hills Estates, Hickory Heights, and Toothman Subdivision, all of which are unsewered. Line P-9 would serve a large planned development called Cooper Homes in the area southeast of Division Street and Highway 65. Line P-10 would serve the Hickory Hills Club House, eliminating the existing treatment facility. Costs are estimated as follow:


BATTLEFIELD ROAD
65
SUNSHINE DRIVE
CHERRY STREET
SPRINGF
P-1
P-2
P-3
P-4
P-5
P-6
P-7
P-8
P-9
JAMES RIVER INTERCEPTOR
PIERSON CREEK INTERCEPTOR
INTCEPT. EXT.
RIDGE LINE
D



DEIS FIGURE 30

PIERSON CREEK BASIN EXHIBIT # 6

Pierson Creek Interceptor (Extension (2.500 L.F.-18" sewer)	$ 119,390
Line P-1 (7,000 L.F.-12" sewer)	219,500
Line P-4 (2,300 L.F.-10" sewer)	59,000
Line P-6 (3,000 L.F.-8" sewer)	63,400
Line P-7 (3,400 L.F.-8" sewer)	72,700
Line P-8 (7,000 L.F.-12" sewer and 2,300 L.F.-15" sewer)	287,800
Line P-9 (2,400 L.F.-10" sewer)	57,150
Total Construction Cost	$878,940
Design	55,500
Construction inspection and management, soils investigation, easements, administrative and legal	344,500
Contingency	88,000
Total Project Cost	$1,366,940

2) James River Basin. The James River interceptor went into operation in early 1981 and will serve some areas projected to develop rapidly over the planning period. In addition to receiving flow from the planned Pierson Creek interceptor and Thompson Branch trunk sewer, there are projected growth areas directly tributary to the James River interceptor. Projected average and peak flows to the James River interceptors are 4.092 and 9.41 MGD in 2005 and 5.988 and 12.87 MGD in 2025, plus possible peak flows from the Half-a-Hill area of 6.32 and 6.50 MGD, respectively. The interceptor design capacity of 32 MGD is thus adequate to handle the 2025 flows.

Short range needs include the Thompson Branch trunk, serving an area immediately north of Lake Springfield, and lines J-2 and J-3 which are directly tributary to James River interceptor (see Figure 31). The Thompson Branch trunk would eliminate the Lakewood Wastewater Treatment Plant and the two Ravenwood pump stations. The Thompson

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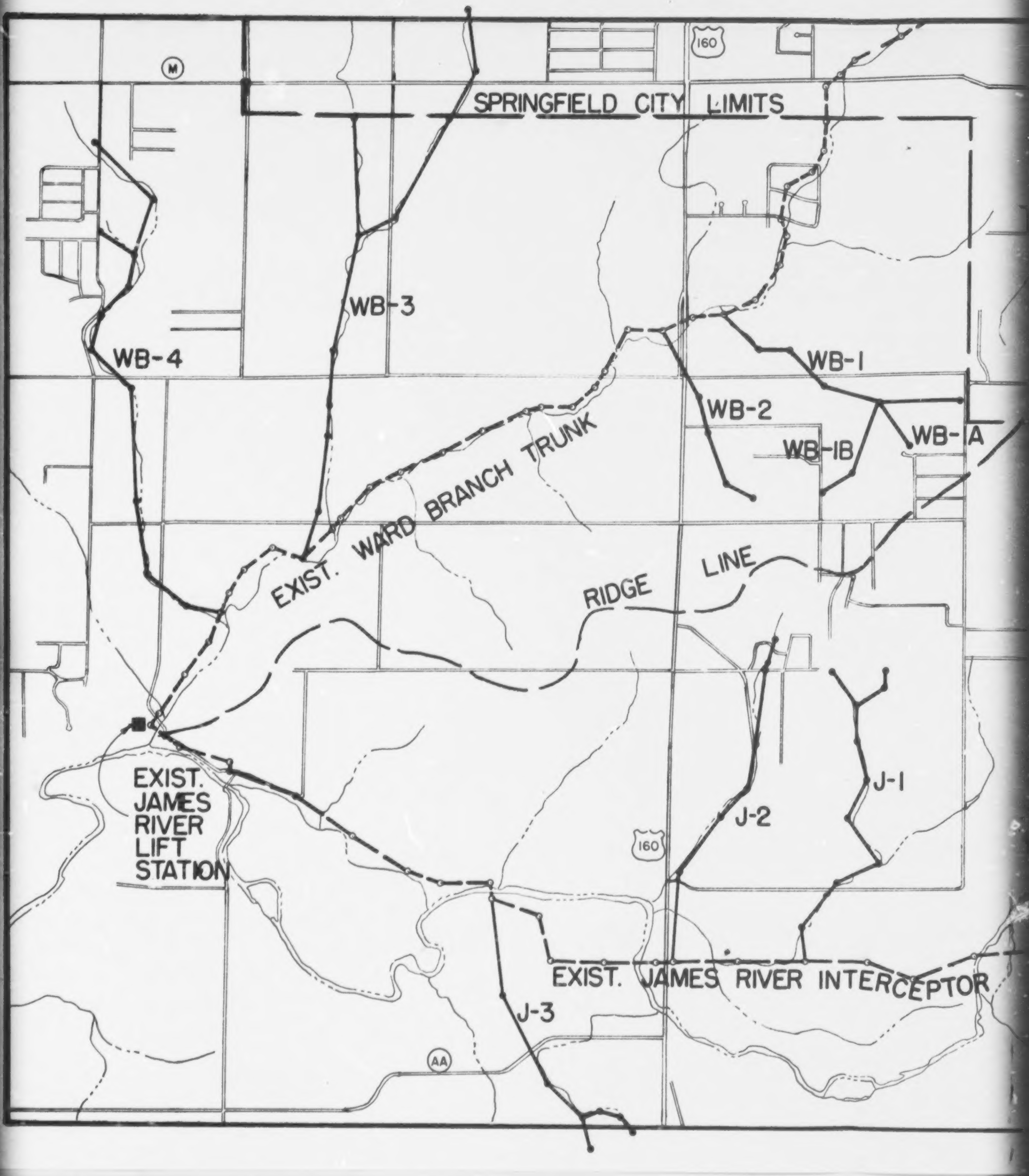
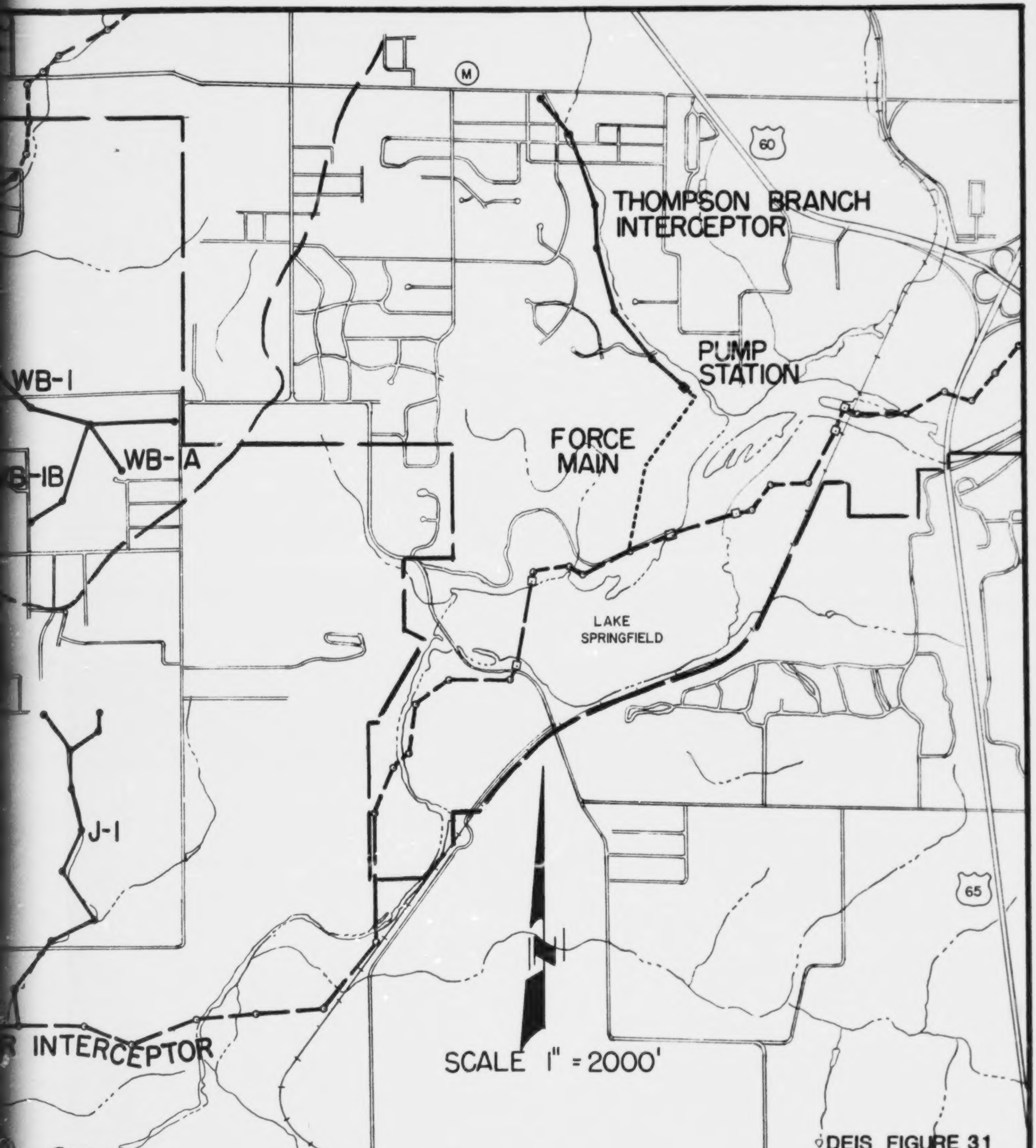
Branch trunk will probably, pending detailed design, require a pump station and force main to deliver flow to the James River interceptor. Line J-2 would serve Town and Country Estates, which has dead sewers, and Rolling Hills, which is unsewered. Line J-3 would serve an area of northern Christian County and eliminate an existing treatment facility serving English Valley Mobile Home Park and Meadow View Subdivision. Costs are estimated as follow:

Thompson Branch Interceptor Construction Cost (6,000 L.F.-15" sewer, pump station with standby generator, and 6,000 L.F.-16" force main)	$535,800
Design	30,000
Construction inspection and management, soils investigation, easements, administrative and legal	190,000
Contingency	54,000
Total Project Cost	$809,800
Line J-2 Construction Cost (6,500 L.F.-10" sewer)	184,000
Design	13,000
Construction inspection and management, soils investigation, easements, administrative and legal	67,500
Contingency	18,000
Total Project Cost	$282,500
Line J-3 Construction Cost (6,200 L.F.-8" sewer)	$149,650
Design	11,000
Construction inspection and management, soils investigation, easements, administrative and legal	66,000
Contingency	15,000
Total Project Cost	$241,650


M
160
SPRINGFIELD CITY LIMITS
WB-3
WB-4
WB-1
WB-2
WB-1B
WB-1A
EXIST. WARD BRANCH TRUNK
RIDGE LINE
EXIST. JAMES RIVER LIFT STATION
J-1
J-2
160
J-3
EXIST. JAMES RIVER INTERCEPTOR
AA



DEIS FIGURE 31

JAMES RIVER BASIN EXHIBIT # 7

Long range needs include line J-1 to serve the existing developments, Cherokee Estates, Cinderella Village, and Pine Oak Place, all of which are presently unsewered. The estimated costs are as follow:

Line J-1 Construction Cost (5,700 L.F.-10" sewer and 1,600 L.F.-8" sewer)	$197,300
Design	13,700
Construction inspection management, soils investigation, easements, administrative and legal	71,500
Contingency	20,000
Total Project Cost	$302,500

3) Ward Branch Basin. The Ward Branch trunk went into operation in mid-1980 and serves a rapidly growing area within and outside the Springfield city limits. The Kickapoo High School and Arrowhead pump stations and the Parkcrest treatment facility have been eliminated with connection to this trunk. There are plans to eliminate the McAllister, Sheraton, and Southvale pump stations in the near future. Average and peak flows are currently 0.1 and 0.2 MGD, and projected to increase to 2.507 and 6.27 MGD in 2005 and 3.676 and 8.64 MGD, respectively, in 2025.

Short range needs include the construction of lines WB-2, WB-3, and WB-4 (see Figure 31). Line WB-2 would eliminate the treatment facility for Cherokee School; line WB-3 would eliminate the Parkcrest pump station; and line WB-4 would serve developments including Holiday hills, Hidden Valley Estates, Glendale Terrace, Southview Terrace, Teton Estates, and Maple Dale. Hidden Valley Estates and portions of Glendale Terrace have dead sewers. Estimated costs are as follows:

Line WB-2 Construction Cost (3600 LF - 10" sewer)	$125,900

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Line WB-3 (Workman Branch) Construction Cost (6000 LF - 18" sewer and 7100 LF - 12" sewer)	531,250
Line WB-4 (10,500 LF - 15" sewer and 700 LF - 8" sewer)	412,800
Total Construction Cost	$1,069,950
Design	67,000
Construction, inspection and management, soils investigation, easements, administrative and legal	261,000
Contingency	107,000
Total Project Cost	$1,504,950

Long range needs include line WB-1 to serve developing areas east of Cherokee School. These areas include Cherokee Corner, Dutch Terrace, and South Downs, and this line would also serve areas within the City of Springfield, west of South Fremont Street. Estimated costs are as follow:

Line WB-1 Construction Cost (3400 LF - 15" sewer, 1500 LF - 12" sewer and 3000 LF - 8" sewer)	$249,900
Design	17,100
Construction, inspection and management, soils investigation, easements, administrative and legal	124,500
Contingency	25,000
Total Project Cost	$416,500

4) Wilsons Creek Basin. The Wilsons Creek interceptor went into service in the late 1970's. It connects to the Upper Wilsons Creek trunk and discharges by gravity into the Southwest Plant. Only minor development exists in the unincorporated areas which are tributary to this interceptor and the only flows now carried are excess I/I overflows from the upper Wilsons Creek trunk. Average and peak flows

are projected at 1.26 and 3.4 MGD in 2005 plus 6.00 MGD peak overflow from the upper Wilsons Creek trunk; and 2.28 and 5.59 MGD in 2025 plus 6.50 MGD peak overflow from the upper Wilsons Creek trunk. This is within the 12.5 MGD design capacity, if I/I does not become worse.

Short range needs include a line planned to serve Hi-View Mobil Home Park which would eliminate a lagoon (see Figure 32). Other needs are downstream of the Southwest Plant and not tributary to the Wilsons Creek interceptor. A line in this area would serve Silver Leaf Shopping Center, Del Prado Hills, Ridgecrest Estates, Newport, Lurvey's Ridgecrest, and Prairie View Heights, and eliminate two pump stations serving Del Prado Hills and treatment facilities serving Silver Leaf Shopping Center and Prairie View Heights. A major pump station would be near Roundtree Spring to pump flows to the Southwest Plant interceptor. The estimated costs are as follow:

Line W-1 and Roundtree Pump Station Construction Cost (5200 LF - 8" sewer, 5300 LF - 10" sewer, 5500 LF - 15" sewer, and standby generator for pump station)	$850,650
Design	50,000
Construction, inspection and management, soils investigation, easements, administrative and legal	280,000
Contingency	85,000
Total Project Cost	$1,265,650
Annual O&M Cost	$ 12,000

There are no identifiable long range needs although significant growth is projected in some areas. Sewers are likely to be installed with this growth in view of current zoning regulations.

5) Summary. Most of the previously discussed short and long term needs will likely be constructed with local financing through the intergovernmental agreement between the City of Springfield and Greene County. The City intends to pursue EPA construction grants for

some major projects including the Thompson Branch trunk sewer, pump station, and force main and the Pierson Creek interceptor and extensions.

2. Northern System

The northern portion of the Springfield system handles about 15 percent of all residential customers served in the city, plus a few industries and large motels. As shown in Figure 28 and Table 31, the Pea Ridge Creek Trunk and the new Airport trunk and pump station are the major conveyance facilities to the Northwest Plant. The force main from the Airport pump station discharges into the Pea Ridge trunk near the plant.

Flow to the Northwest Plant currently averages about 3.5 MGD, equal to the plant design capacity. Peak day flow is 7.5 MGD while average dry weather flow is about 2.4 MGD. Added treatment capability and capacity and handling excessive I/I are critical needs of the northern system. In 1978 and 1981, heavy rains caused the dikes protecting the plant to be topped and serious flood damage and disruption of the treatment plant occurred. Other northern system considerations and concerns are trunk and interceptor sewers, sludge processing and disposal, effluent reuse, and land application treatment.

a. Northwest Treatment Plant. A summary of current and projected flow, BOD, and suspended solids loadings to the Northwest Plant system and comparative design capacities of the existing plant are given in Table 32. Basic alternatives for the system are no action, abandoning the existing plant and building a new plant at one of two downstream sites, and expanding and upgrading the existing Northwest Plant (see Figure 29).

The Little Sac River is water quality limited with the following requirements*:

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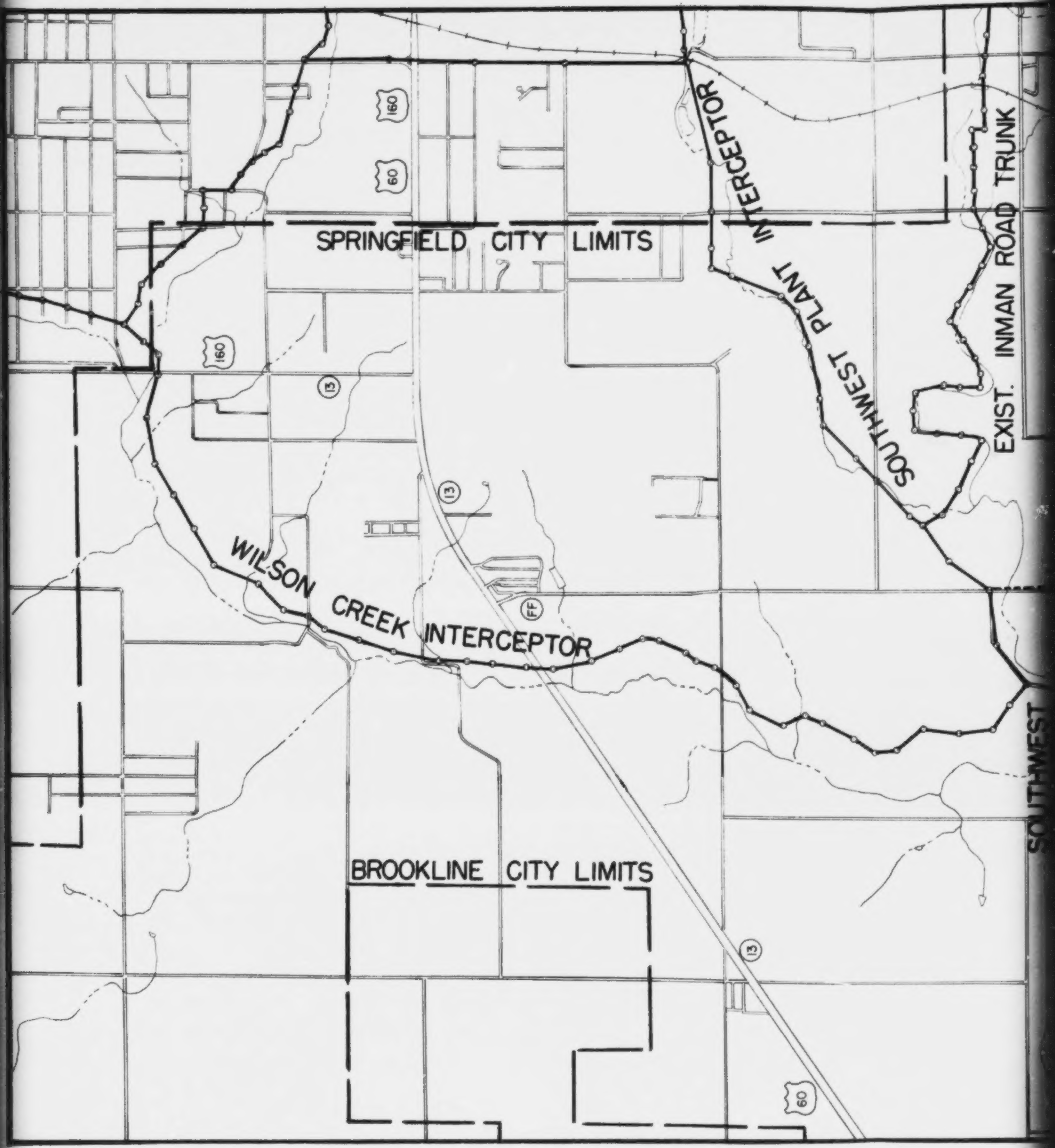
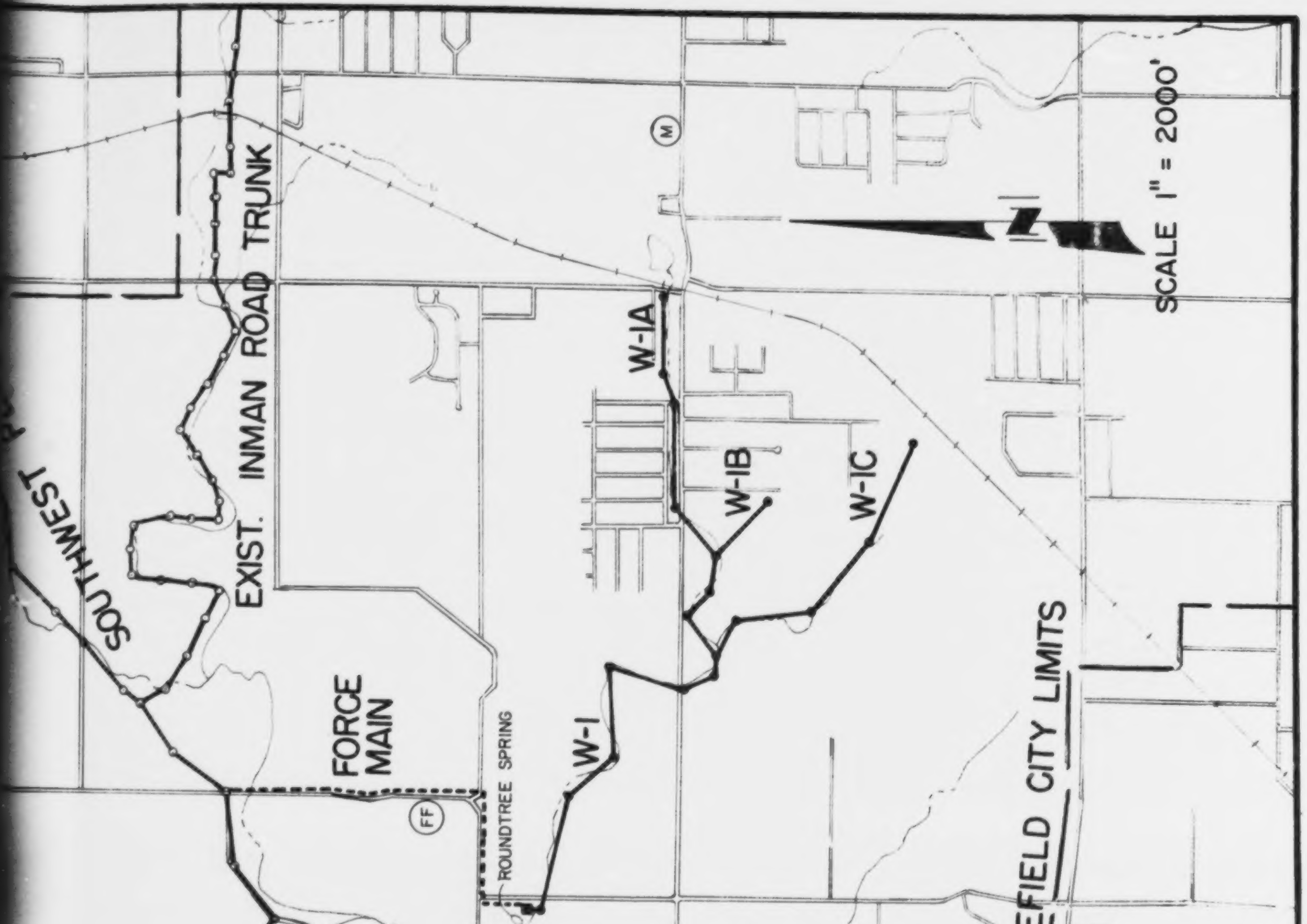
* Updated waste load allocation studies are being conducted by the MDNR to determine requirements for increasing the Northwest Plant capacity. The existing effluent requirements are based on earlier studies and are being used in the interim.


160
60
SPRINGFIELD CITY LIMITS
SOUTHWEST PLANT INTERCEPTOR
EXIST. INMAN ROAD TRUNK
160
13
13
FF
WILSON CREEK INTERCEPTOR
SOUTHWEST
BROOKLINE CITY LIMITS
13
60



DEIS FIGURE 32

WILSON CREEK BASIN

EXHIBIT # 8

TABLE 31
CITY OF SPRINGFIELD
NORTHERN SYSTEM
MAJOR SEWER CAPACITIES AND FLOWS

Facility	Size Dia.	Capacity	Average Flow	Peak Flow	Design PE
Pea Ridge Creek (at NW plant)	30"	6.5 MGD	2.0 MGD	9.0 MGD (surcharged)	30,000
Airport Trunk (at Airport Pump Sta.)	30"	20.0 MGD	Newly Constructed		100,000

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TABLE 32
NORTHWEST TREATMENT PLANT
CURRENT AND PROJECTED WASTE LOADINGS

Parameter	Existing Plant Design	Current*	Projected 2005
Flow (MGD)			
- Average Day	3.5	3.2	6.0
- Peak Hydraulic	5.25	--	--
- Dry Weather	--	2.4	4.8
- Peak Day	--	7.1	9.9
- Peak Rate	--	9.0	16.3
BOD (lb/day)			
- Average Day	9500	4700	9700
Susp. Solids (lb/day)			
- Average Day	6900	4200	9100

*Representative data, 1979 to 1982.

	Weekly Average	Monthly Average
BOD (mg/l)	15	10
SS (mg/l)	20	15
pH	6.0 to 9.0	
Ammonia (mg/l)	2	

1) No Action. The treatment plant would remain as it is. The existing plant is overloaded and was not designed to meet current effluent requirements, much less handle additional loads.

2) Plant Relocation - Murray Site. (Proposed in Draft Facilities Plan) The existing treatment plant would be abandoned and a new plant of expanded capacity would be built about 15,000 ft downstream on a tract of land of the City's abandoned Murray landfill site. The portion of the site that would be used for the plant has never been landfilled.

The planned treatment process, as shown in Figure 33, is a two-stage biological treatment system providing carbonaceous BOD reduction in the first stage and ammonia reduction in the second stage. Several alternative treatment methods, as shown in Figure 33 and Table 33, were compared for each stage. Recommended cost-effective methods are orbal aeration for the first stage and submerged aerated rock filtration for the second stage.

The submerged aerated filters are expected to achieve the effluent limits without requiring final clarification or granular filtration as would be needed with other second-stage (nitrification) treatment process alternatives. This represents a relatively new and innovative process which is not fully demonstrated by similar full-scale plant applications. Effluent filtration could be added later if required.*

The capital cost of the total treatment system is estimated to be $9,351,700 ($8,868,600 present worth) if effluent filtration is needed, and $7,566,200 ($7,149,500 present worth) if effluent filtration

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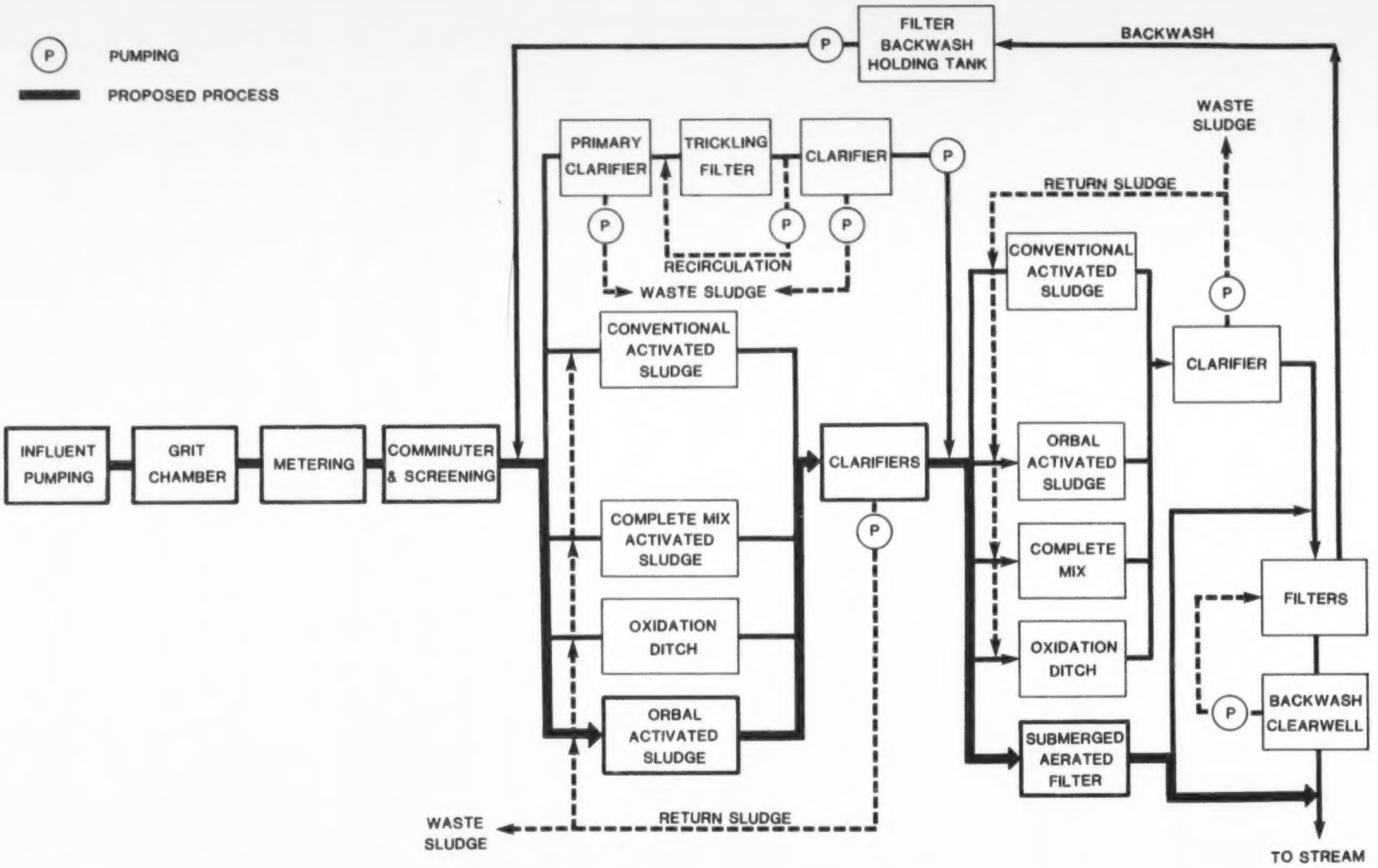
* The selected treatment process could be different, depending upon final design decisions.



GREENE COUNTY SEWER DISTRICT
SPRINGFIELD SUBAREA
NORTHWEST WASTEWATER TREATMENT PLANT
TREATMENT ALTERNATIVES

FIGURE 33

TABLE 33
CAPITAL, ANNUAL O&M, AND TOTAL ANNUAL EQUIVALENT COSTS
NORTHWEST WASTEWATER TREATMENT PLANT
TREATMENT PROCESS ALTERNATIVES

Nitrification Treatment / Carbonaceous Treatment	Conventional Activated Sludge	Complete Mix Activated Sludge	Oxidation Ditch	Orbal	Submerged Filter
Trickling Filter					
Capital	$13,111,500	$12,226,800	$11,815,500	$11,618,800	$10,446,200
Annual O&M	759,000	738,000	648,000	621,000	600,000
Total Annual	1,989,100	1,885,300	1,753,600	1,708,900	1,582,700
Conventional Activated Sludge					
Capital	$13,397,400	$12,512,800	$12,101,400	$11,904,600	$10,732,100
Annual O&M	826,000	807,000	716,000	689,000	660,000
Total Annual	2,083,900	1,981,500	1,847,800	1,802,900	1,669,400
Complete Mix Activated Sludge					
Capital	$12,263,600	$11,378,800	$10,867,500	$10,770,700	$ 9,597,700
Annual O&M	795,000	776,000	685,000	658,000	630,000
Total Annual	1,948,400	1,846,000	1,712,300	1,667,400	1,533,800
Oxidation Ditch					
Capital	$12,107,800	$11,223,500	$10,812,100	$10,615,400	$ 9,442,400
Annual O&M	790,000	771,000	680,000	653,000	624,000
Total Annual	1,927,000	1,824,600	1,690,900	1,646,100	1,512,400
Orbal					
Capital	$12,014,300	$11,134,900	$10,723,600	$10,526,800	$ 9,351,700
Annual O&M	784,000	765,000	674,000	647,000	618,000
Total Annual	1,913,600	1,811,600	1,678,000	1,630,800	1,499,200

is not required. Total annual costs are estimated at $1,499,200 and $1,325,800, respectively. The new 15,000-ft Little Sac interceptor sewer is estimated to cost an additional $3,235,000.

3) Plant Relocation - Highway 13 Site. The existing treatment plant would be abandoned and a new plant of expanded capacity would be built about 10,000 ft downstream of the existing plant on land between old and new Highway 13. Treatment would be the same as at the Murray site. Although closer to the existing plant, severe site limitation problems exist. Rock outcroppings, topography variations, identified archeological sites, and limited room for expansion render this site much less suitable for the plant relocation.

4) Expansion of Existing Plant. Expansion and upgrading of the existing plant were not found to be practical. Additional flood protection, including a new access bridge roadway, would be required. Plant additions would have to be constructed on a landfill area, posing serious structural problems. Many plant facilities are about 50 years old and would require extensive rehabilitation.

5) Land Application and Reuse. The land application alternative has a present worth cost of $13,591,600 and total annual cost of $2,238,600. The main factors resulting in high costs are the distances to and higher elevation of sites. Factors such as realistically being able to negotiate agreements with owners of the required 5,000 acres of land, providing adequate holding basins without encountering geological and soil problems, and location of homesites further weigh against the land application alternative.

Reuse of effluent was also considered; however, there are no existing or future potential users of the effluent in the quantity produced by the Northwest Plant.

b. Sludge Treatment and Disposal. A sludge holding tank and aerobic digester are recommended for the waste activated sludge stabilization. Belt filter press dewatering equipment for the sludge is also proposed. A 45-day digester detention time will be provided for sludge stabilization and pathogen die-off as required by MDNR.

Flexibility in the options for ultimate disposal will be provided as follows:

- Haul liquid sludge and dispose of on one existing and two abandoned landfill sites.
- Haul sludge cake for disposal on landfill sites.
- Haul sludge cake for disposal with solid wastes.
- Haul sludge cake for disposal on nearby farmland.

c. Interceptor and Trunk Sewers. There are approximately 14,000 acres tributary to the proposed South Dry Sac interceptor sewer, including about 1,800 acres identified as an unincorporated growth area (generally north of the Springfield city limits, south of the South Dry Sac River, east of Highway 13, and west of Valley Water Mill). There are presently about 850 residents in this area and this population is projected to increase to an estimated 9,000 by the year 2025.

Sewer needs include the 37,100-ft South Dry Sac interceptor and lines S-1, S-2, and S-3 to serve areas which currently use lift stations to pump into the Pea Ridge interceptor (see Figure 34). Costs are estimated as follows:

South Dry Sac Interceptor (1,300 L.F. - 12" sewer, 10,600 L.F. - 15" sewer, 12,500 L.F. - 18" sewer, and 12,700 L.F. - 21" sewer)	$2,090,050
Line S-1 (4,300 L.F. - 12" sewer)	111,300
Line S-2 (1,000 L.F. - 8" sewer)	19,150
Line S-3 (2,800 L.F. - 8" sewer)	46,800
Total Construction Cost	$2,267,300
Design	135,000
Construction inspection and management, soils investigation, easements, administrative, and legal	566,000
Contingency	227,000
Total Project Cost	$3,195,300

B. BATTLEFIELD SUBAREA

The Battlefield subarea is presently served by approximately 684 individual wastewater disposal systems and an extended aeration treatment plant serving 52 residences in one subdivision. Planning for the subarea is based upon existing and projected design year population as follows:

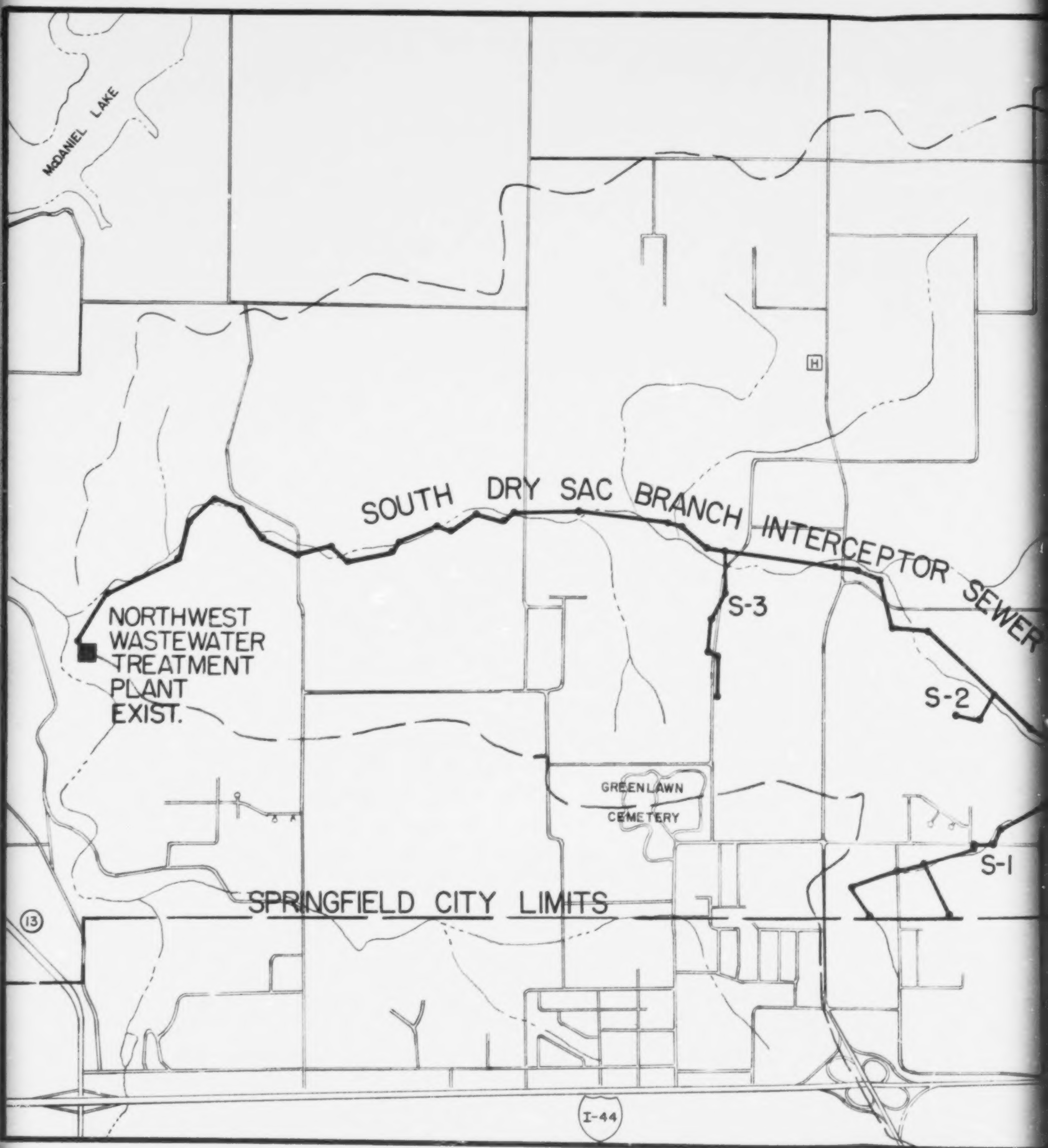
	Population	
	1980	2005
Battlefield Residents	1,227	3,210
Unincorporated Residents	963	3,856
TOTAL	2,190	7,066

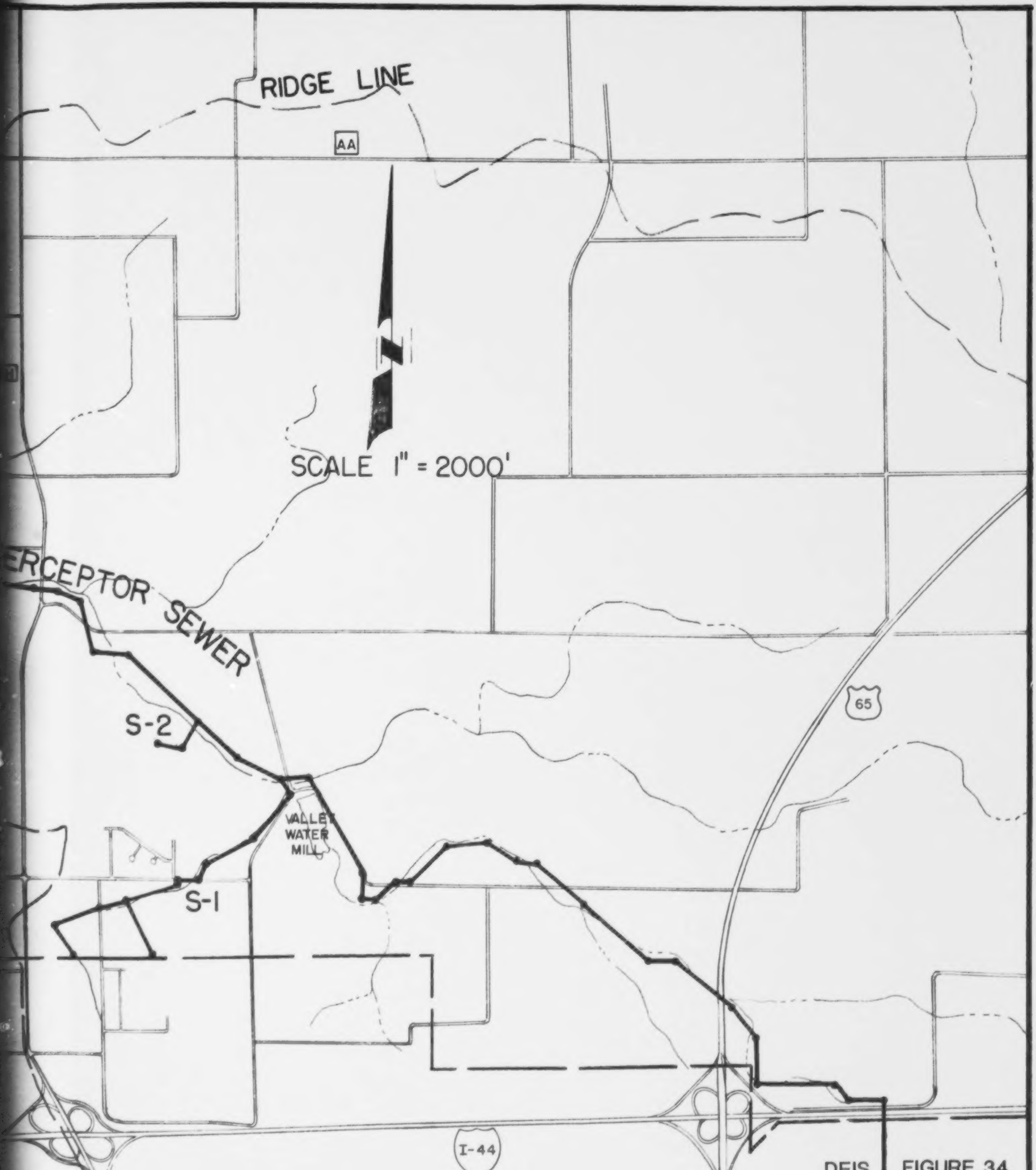
At the design population of about 7,070, the average dry weather design flow at 87 gpcd (existing water supply use) is 0.615 mgd.

Alternatives evaluated for the subarea (see Figures 35, 36, and 42-Republic subarea) are 1) no action (or improvement of existing systems), 2) a treatment plant discharging to Indian Springs Branch, 3) a treatment plant discharging to the James River, 4) a regional pump station to Springfield's James River Pump Station, 5) a regional pump station to Springfield's Southwest Treatment Plant, and 6) land application. Preliminary evaluation of a regional treatment plant to serve Battlefield, Brookline, and Republic indicated extremely high costs, particularly for Republic. This alternative was thus eliminated from further consideration. For the central collection and treatment systems, gravity, pressure, and combination collection and on-site system alternatives are included. Total project, annual O&M, and total annual costs of the alternatives for serving the entire subarea are presented in Table 34.

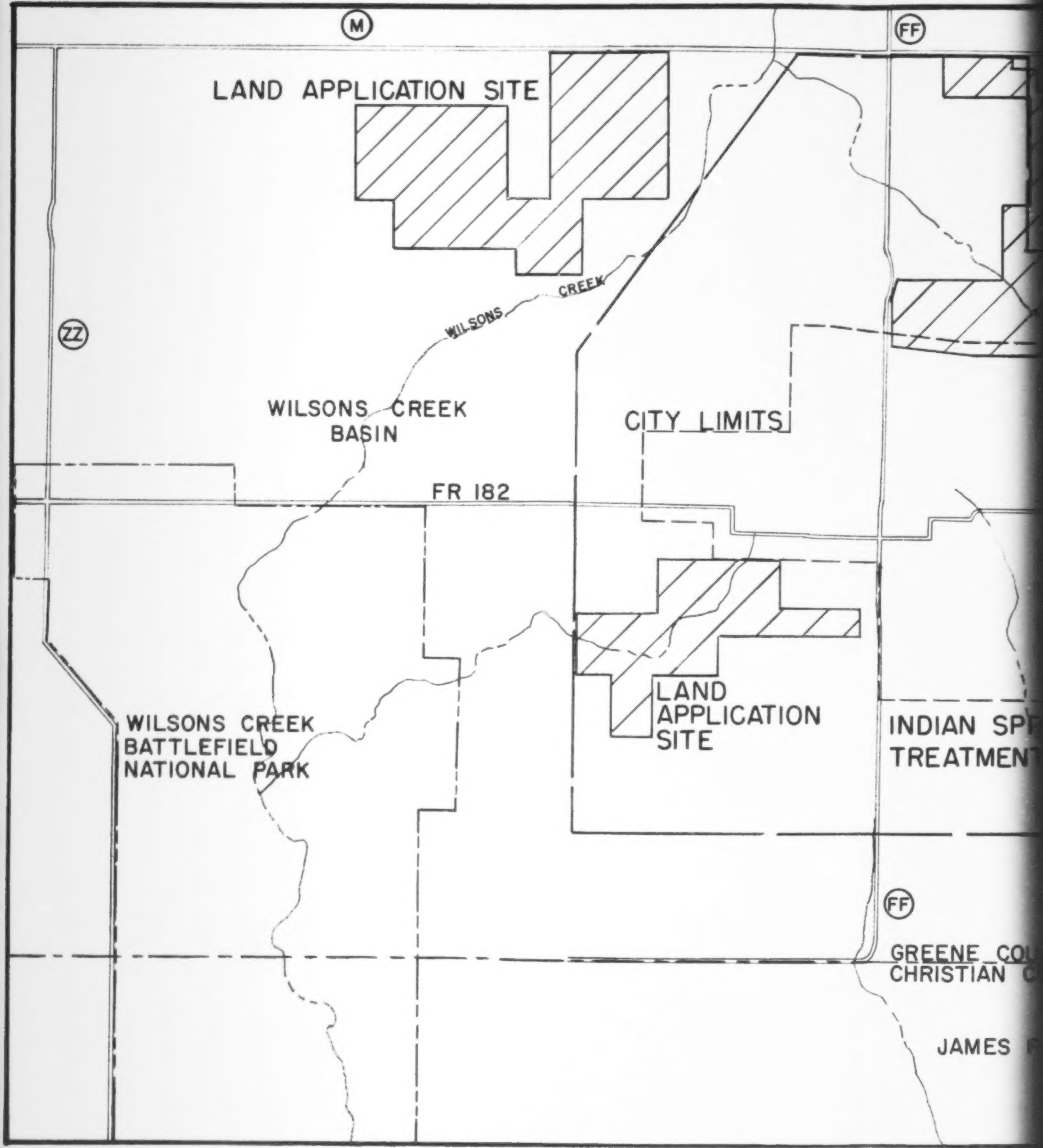
1. No Action

Without federal and state funding assistance, it is unlikely that any central collection and treatment system could be financed. No action alternatives mean continued use of existing septic tank and small treatment plant systems and installation of new ones. The City of


McDANIEL LAKE
SOUTH DRY SAC BRANCH INTERCEPTOR SEWER
H
NORTHWEST WASTEWATER TREATMENT PLANT EXIST.
S-3
S-2
GREENLAWN CEMETERY
S-1
SPRINGFIELD CITY LIMITS
13
I-44



SOUTH DRY SAC INTERCEPTOR EXHIBIT # 9


M
FF
LAND APPLICATION SITE
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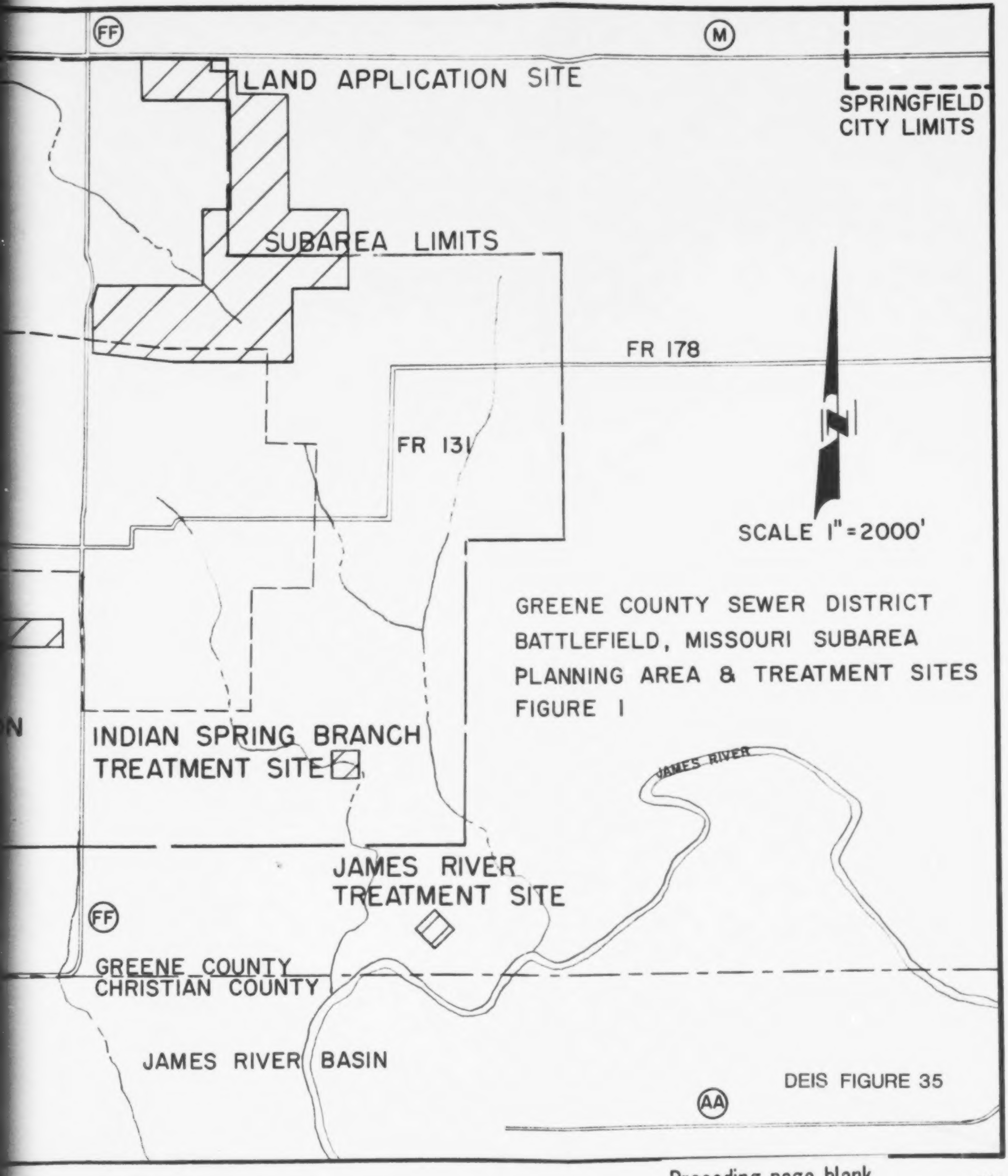
WILSONS CREEK
WILSONS CREEK BASIN
CITY LIMITS
FR 182
LAND APPLICATION SITE
WILSONS CREEK BATTLEFIELD NATIONAL PARK
INDIAN SPR
TREATMENT
FF
GREENE COU
CHRISTIAN C
JAMES R



GREENE COUNTY SEWER DISTRICT
BATTLEFIELD, MISSOURI SUBAREA
PLANNING AREA & TREATMENT SITES
FIGURE 1

DEIS FIGURE 35

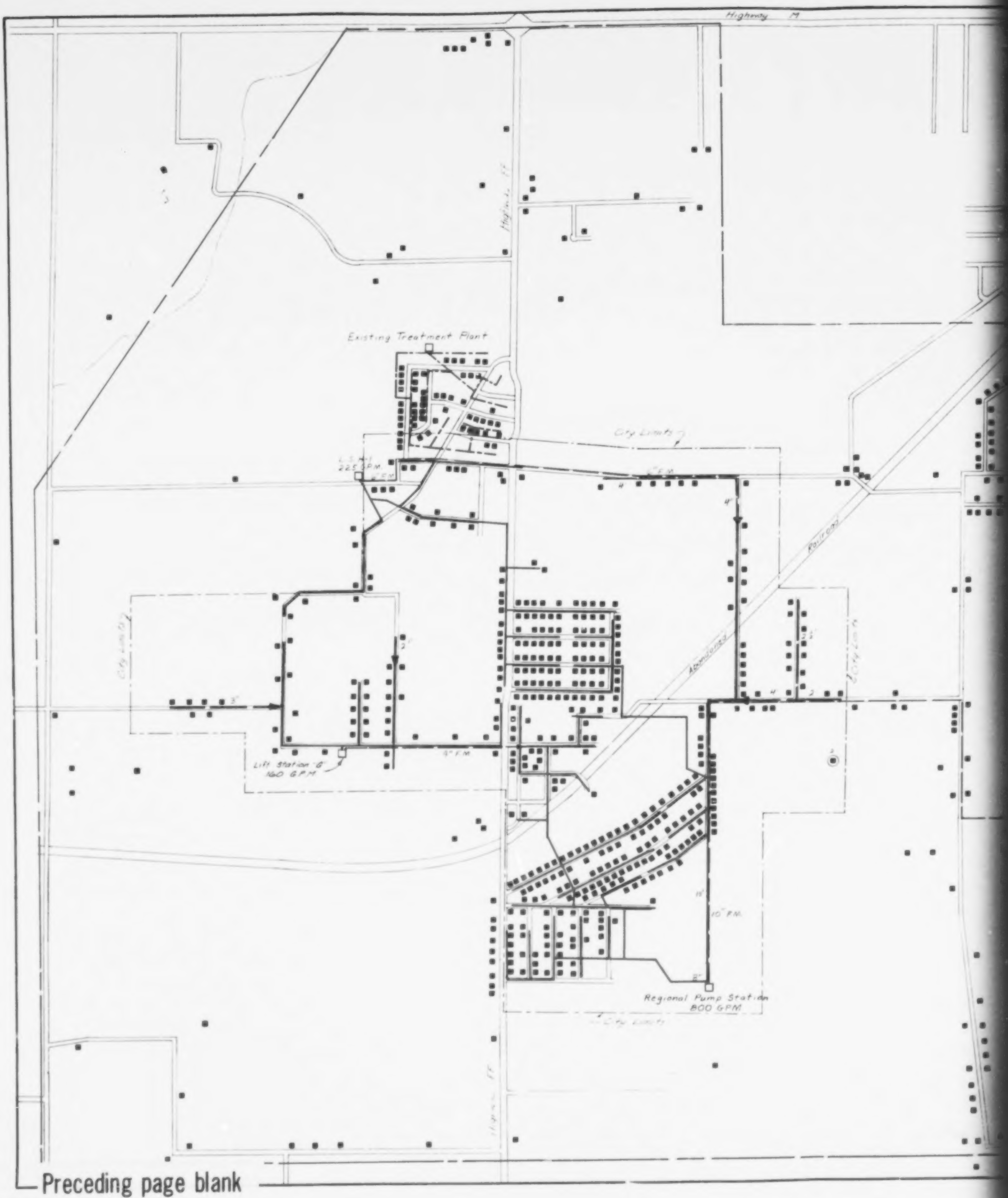


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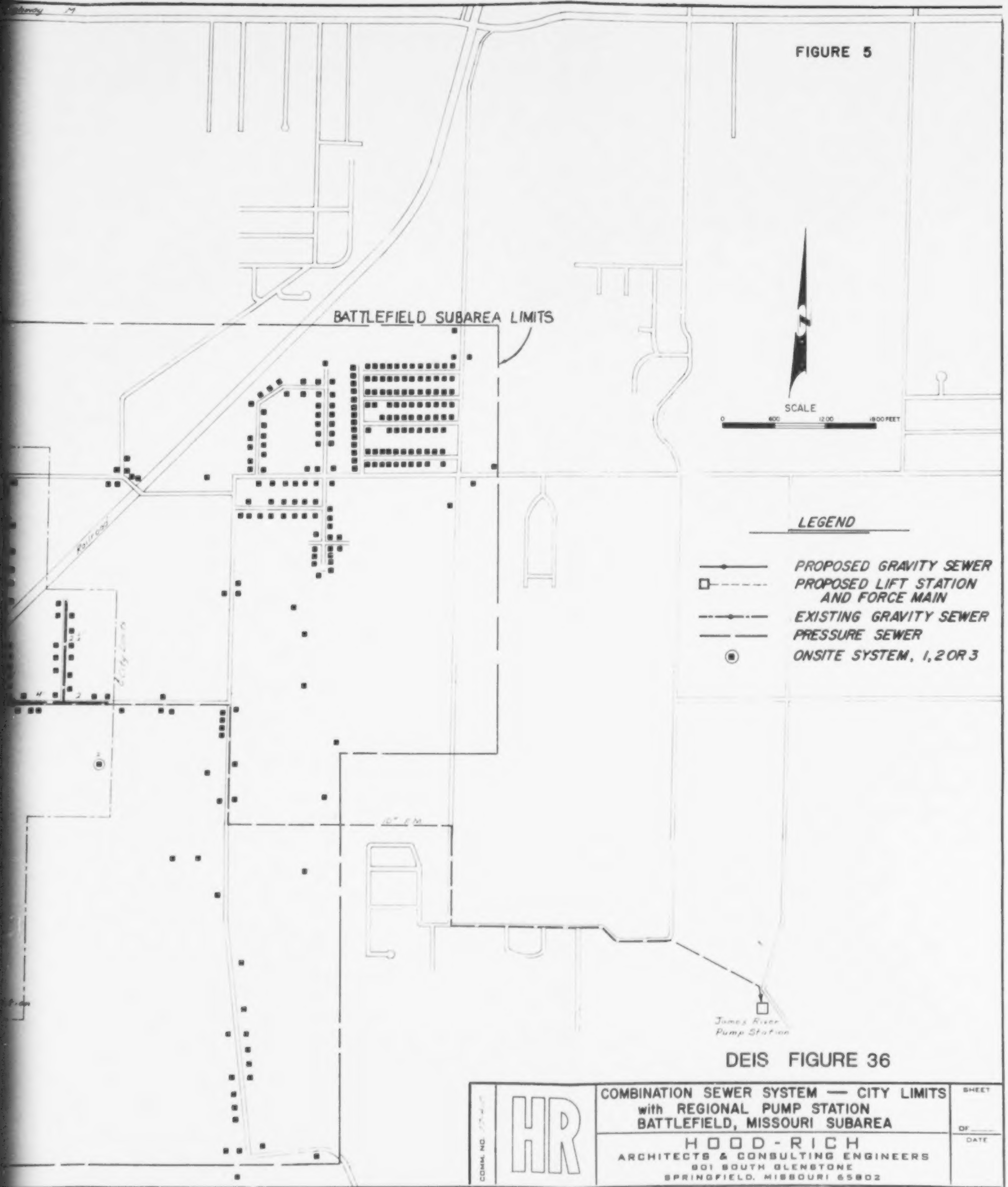
FIGURE 5



LEGEND

- PROPOSED GRAVITY SEWER
- PROPOSED LIFT STATION AND FORCE MAIN
- EXISTING GRAVITY SEWER
- PRESSURE SEWER
- ◉ ONSITE SYSTEM, 1, 2 OR 3

DEIS FIGURE 36

COMBINATION SEWER SYSTEM — CITY LIMITS
with REGIONAL PUMP STATION
BATTLEFIELD, MISSOURI SUBAREA

HR

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

COMM. NO.

SHEET

OF

DATE

TABLE 34
BATTLEFIELD SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Indian Springs Branch Plant			
Pure Gravity	$6,378,000	$ 64,020	$679,770
Pure Pressure	5,578,200	88,875	836,930
Combination	5,469,600	53,460	646,935
James River Plant			
Pure Gravity	6,550,700	62,895	693,585
Combination	5,771,400	51,765	665,725
Regional Pump Station to James River Pump Station			
Pure Gravity	5,242,000	130,505*	638,575
Combination	4,373,600	120,500*	606,300
Regional Pump Station to Southwest Plant			
Pure Gravity	5,525,600	132,260*	665,020
Combination	4,838,600	121,135*	648,975
Land Application Combination	6,124,100	176,000	823,183

* Includes estimated treatment cost.

Battlefield and Greene County may control and manage on-site systems to varying degrees. Soil and geological limitations preclude the longer term acceptability of on-site systems in many areas.

2. Indian Springs Branch Treatment Plant

Indian Springs Branch is a losing stream and losing stream effluent requirements apply (refer to Table 6). The discharge location is approximately 0.9 mile above the confluence with the James River.

The treatment system for meeting effluent requirements would consist of an oxidation ditch, two clarifiers, gravity sand filtration, and chlorine disinfection. Effluent quality of 2 to 10 mg/l BOD and 1 to 10 mg/l SS is expected.

3. James River Treatment Plant

The James River is water quality limited based upon waste load allocations with the following requirements:

	Monthly Average	Weekly Average
BOD (mg/l)	10	15
SS (mg/l)	15	20
pH	6.0 to 9.0	
Ammonia (mg/l)	2	
Fecal Coliform (per 100 ml)	200	

The treatment system for meeting effluent requirements would be the same as that for the Indian Springs Branch treatment plant.

4. Regional Pump Station to James River Pump Station (Proposed in Draft Facilities Plan).

A pump station and force main would be installed southeast of Battlefield to deliver raw wastewater to Springfield's James River Pump Station and Southwest Treatment Plant (see Figure 36). An emergency electric generator is provided in case of power outage.

The scope of the proposed project is to provide a combination gravity and pressure collection system and to initially serve about 1,625 persons or 408 customers within the Battlefield city limits only. The total capital cost of this more limited project is estimated at $2,483,400. Average dry weather flow would be 0.141 MGD initially. The year 2005 population served is projected at 3210 with an average dry weather flow of 0.279 MGD. Depending upon an appropriate intergovernmental agreement, operation and maintenance, as well as treatment, would be the responsibility of the City of Springfield, and Springfield's normal sewer service charges would be billed to Battlefield customers.

5. Regional Pump Station to Southwest Treatment Plant

A pump station and force main would be installed northwest of Battlefield to deliver raw wastewater directly to Springfield's Southwest Treatment Plant. An emergency electric generator is provided in case of power outage.

6. Land Application

A 1.32-acre aerated lagoon and center pivot spray irrigation system would be provided. A 31.2-acre sealed storage basin with 5½ months capacity would hold the lagoon effluent during the winter. Monitoring wells and fencing are provided. At a low application rate of 15 inches per year because of soil limitations, 551 acres are required for the application site. Costs include land purchase for the lagoon and storage basin, but application would be on private land. The soils and geological limitations, storage requirements, and related high costs make land application unfeasible.

C. BROOKLINE SUBAREA

The Brookline subarea is presently served by individual wastewater disposal systems and a mobile home park with a package treatment plant and effluent polishing. Planning for the subarea is based upon existing and projected design year population as follows:

	1980	2005
Brookline Residents	211	298
Unincorporated Residents	302	302
Total	513	600

At the design population of 600, the average dry weather design flow at an estimated 65 gpcd* is 0.039 mgd.

---

* Brookline does not have a community water supply system; therefore, actual water use figures are not available.

Alternatives evaluated for the subarea (refer to Figures 37, 38, and 42-Republic subarea) are 1) no action (or improvement of existing systems), 2) treatment plants discharging to Pond Creek at six alternative sites, 3) a regional pump station to Republic, and 4) a regional pump station to Springfield. Land application in the Brookline subarea and surrounding areas is not feasible because of extensive sinkhole development and other karst topography features. Lagoons or storage basins, integral parts of a land application system, would have a high risk of failure due to sinkhole collapse. For central collection and treatment systems, gravity, pressure, and combination collection and on-site system alternatives were evaluated. Total project, annual O&M, and total annual cost estimates of the alternatives for serving the entire subarea are presented in Table 35.

1. No Action

Without federal and state funding assistance it is unlikely that any central collection and treatment alternative could be financed. No action alternatives mean continued use of existing septic tank and small treatment plant systems and installation of new ones. Brookline and Greene County may control and manage on-site systems to varying degrees. Soil and geological limitations preclude the longer term acceptability of on-site systems in many areas.

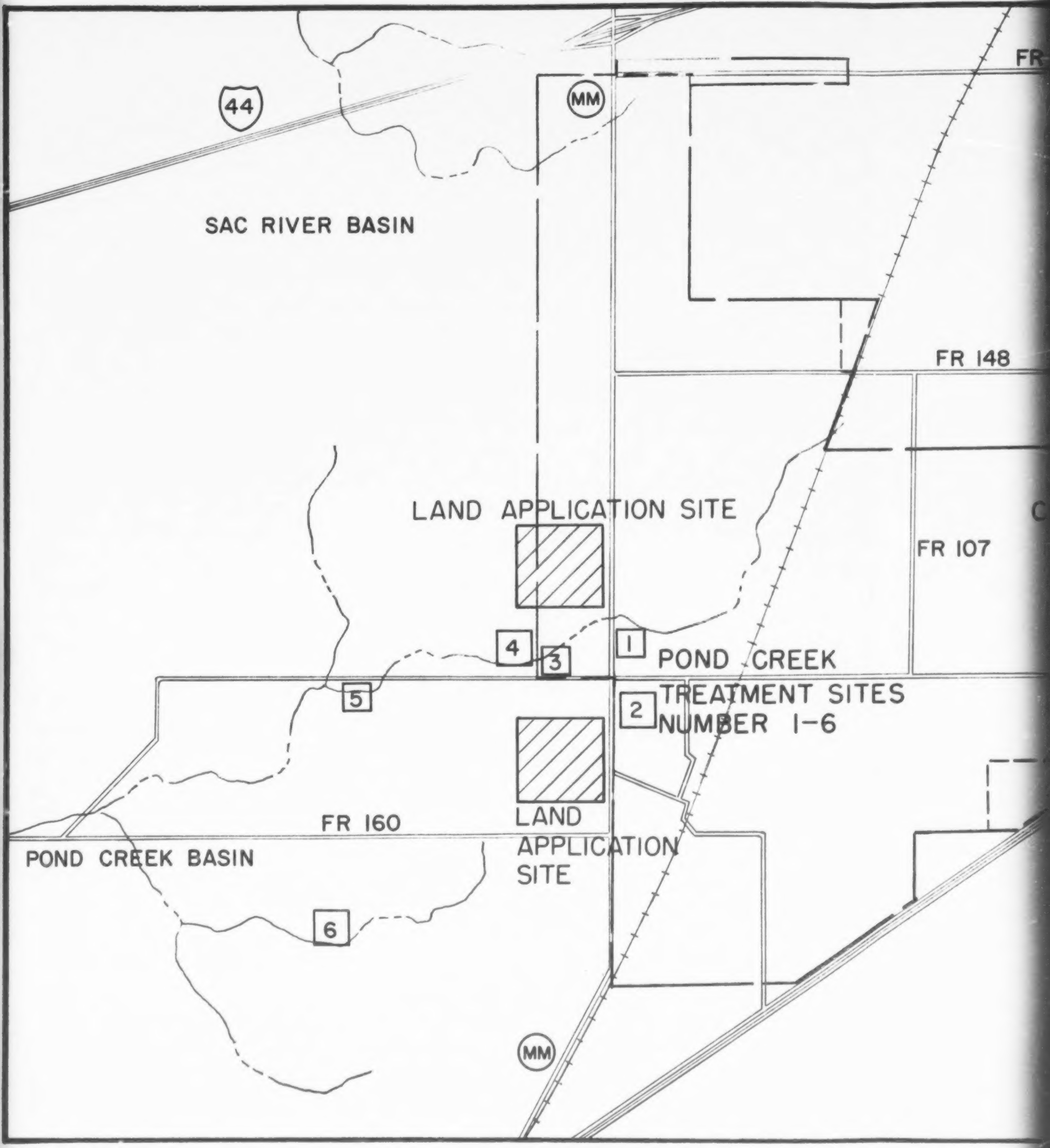
2. Pond Creek Treatment Plants, Site Nos. 1 through 6

Pond Creek is a losing stream, and losing stream effluent requirements apply at all sites (refer to Table 6).

The treatment system for meeting effluent requirements would consist of an extended aeration system, one clarifier, a recirculating rock filter, and chlorine disinfection. Effluent quality of 10 mg/l BOD, 15 mg/l SS, and less than 200 fecal coliform per 100 ml can be expected.

3. Regional Pump Station to Republic

A pump station and force main would be installed to deliver raw wastewater to Republic's system.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FR
SAC RIVER BASIN
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LAND APPLICATION SITE
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POND CREEK
TREATMENT SITES
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APPLICATION
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FR 160
POND CREEK BASIN
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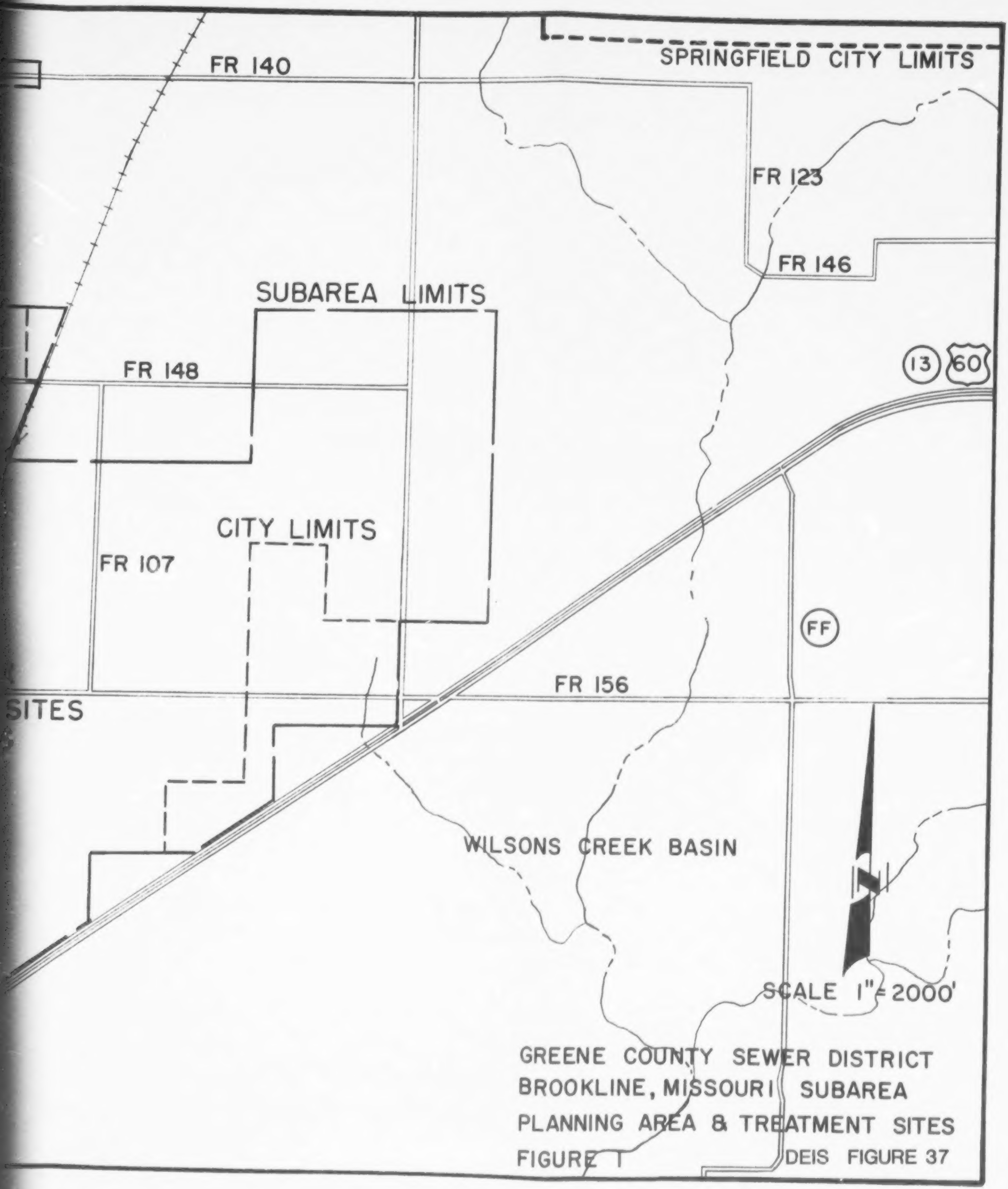

GREENE COUNTY SEWER DISTRICT
BROOKLINE, MISSOURI SUBAREA
PLANNING AREA & TREATMENT SITES
FIGURE 1
DEIS FIGURE 37

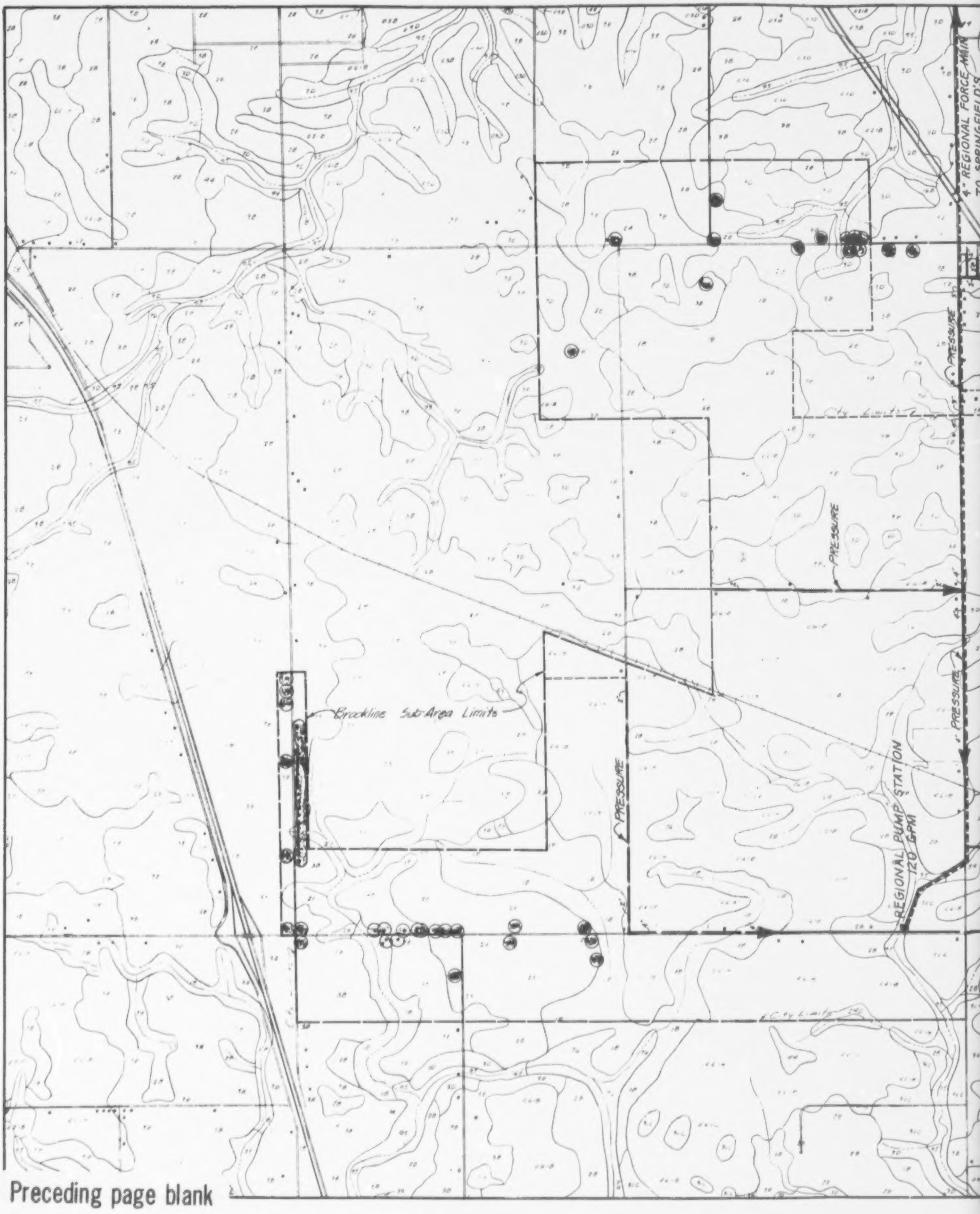

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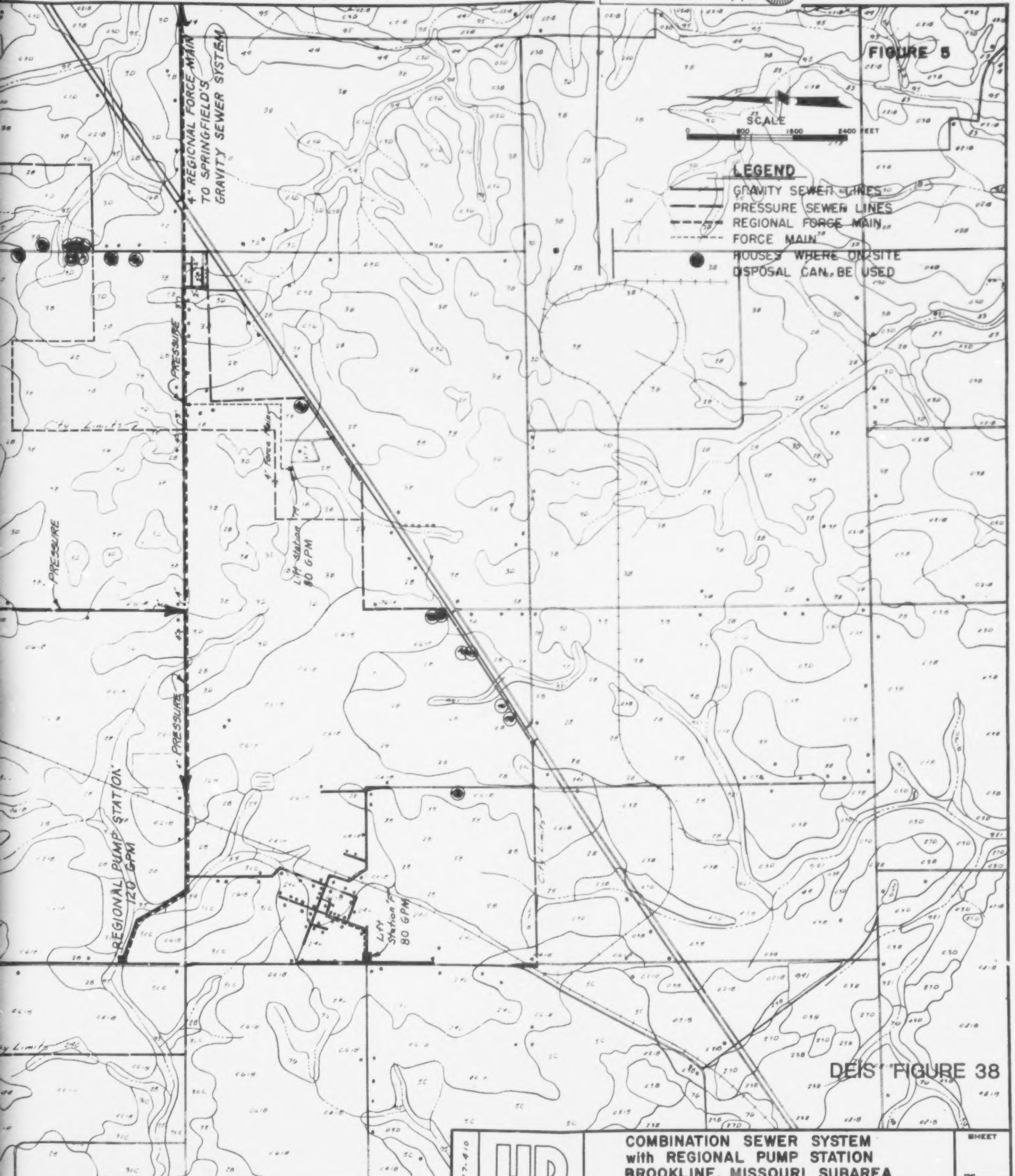
FIGURE 5



DEIS' FIGURE 38

COMM. NO. 77-410

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COMBINATION SEWER SYSTEM
with REGIONAL PUMP STATION
BROOKLINE, MISSOURI SUBAREA

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

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7/11/83

TABLE 35
BROOKLINE SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Pond Creek Plant Site #1			
Pure Gravity	$2,688,400	$ 47,965	$291,200
Pure Pressure	1,801,400	40,700	218,735
Combination	1,980,030	31,270	227,870
Pond Creek Plant Site #2			
Pure Gravity	2,723,200	48,160	294,290
Pure Pressure	1,801,400	40,700	218,735
Combination	1,911,330	30,810	221,605
Pond Creek Plant Site #3			
Pure Gravity	2,700,600	47,360	291,285
Pure Pressure	1,830,600	40,700	221,345
Combination	1,989,030	30,585	227,610
Pond Creek Plant Site #4			
Pure Gravity	2,724,200	47,360	293,285
Pure Pressure	1,848,300	40,700	222,940
Combination	2,012,600	30,585	229,615
Pond Creek Plant Site #5			
Pure Gravity	2,753,900	47,360	295,820
Pure Pressure	1,859,700	40,700	223,970
Combination	2,042,300	30,585	232,140
Pond Creek Site #6			
Pure Gravity	2,792,200	47,555	299,290
Pure Pressure	1,877,600	40,700	225,485
Combination	2,077,100	30,585	235,090
Regional Pump Station to Republic			
Pure Gravity	2,859,000	54,770*	311,020
Pure Pressure	1,937,500	47,310*	235,490
Combination	2,100,700	36,520*	241,730
Regional Pump Station to Springfield			
Pure Gravity	2,553,000	61,285*	289,785
Pure Pressure	1,631,000	53,825*	214,205
Combination	1,562,400	43,520*	197,980

* Includes estimated treatment costs.

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4. Regional Pump Station to Springfield (Proposed in Draft Facilities Plan)

A pump station and force main would be installed to deliver raw wastewater to the Southwest Treatment Plant via Springfield's Wilsons Creek interceptor (see Figure 38). The force main will consist of 1,200 feet of 4-inch ductile iron pipe. An emergency overflow basin with 24-hour holding capacity will be provided at the pump station. Chlorination will be provided to help prevent the wastewater from becoming septic. A combination gravity and pressure sewer collection system will serve much of the subarea but on-site systems will continue in use in some areas. The pump station and force main are sized to serve the entire subarea.

The total capital cost of this more limited project is estimated at $1,301,800. Depending upon an appropriate inter-governmental agreement, operation and maintenance, as well as treatment, would be the responsibility of the City of Springfield, and Springfield's normal sewer service charges would be billed to Brookline customers.

D. FAIR GROVE SUBAREA

The Fair Grove subarea is presently served by about 350 individual wastewater disposal systems; three lagoon systems serving a trailer park, a senior citizens housing project, and an individual home; and a septic tank-rock filter system for the Fair Grove School. Planning for the subarea is based on 1980 and projected design year population as follows:

Population Equivalents

	1980	1995	2005
Fair Grove Residents	863	1,501	1,929
Non-Resident Students	200 (800)*	234 (936)*	300 (1,200)*
Businesses	86	201	259
Total	1,149	1,936	2,488

*Number of students from surrounding areas; the population equivalent for determining waste load equals 0.25 times the number of students.

The year 2005 design population equivalent is thus about 2,490 and the average wet weather (including I/I) design flow at 100 gpcd* is 0.249 MGD. A ten-year phasing of facilities was evaluated.

Alternative plans for the subarea (refer to Figures 39, 40 and 41) are 1) no action (or improvement of on-site systems), 2) a treatment plant at Site #1 discharging to the Pomme de Terre River, 3) a treatment plant at Site #2A (revised from original Site #2) discharging to a branch tributary to the Pomme de Terre River, 4) a treatment plant at Site #3 discharging to the Little Pomme de Terre River, 5) a regional pump station and force main to Strafford, and 6) land treatment at two potential sites. For the central collection and treatment systems, gravity, pressure, and combination collection and on-site system alternatives are presented. Cluster systems are also considered. Treatment alternatives considered are oxidation ditch, trickling filter, and lagoon systems.

Total project, annual O&M, and total annual costs of the alternatives for serving the entire subarea are presented in Table 36.

1. No Action

Without federal and state funding assistance, it is unlikely that any central collection and treatment system could be financed. No action alternatives mean continued use of existing septic tank and small treatment systems and installation of new ones. The City of Fair Grove and Greene County may control and manage on-site systems to varying degrees. Soil and geological conditions preclude the longer term acceptability of on-site systems in many areas.

2. Pomme de Terre River Treatment Plant, Site #1

The Pomme de Terre River is a gaining stream and classified for whole body contact recreation. Gaining stream effluent requirements and fecal coliform limits apply (refer to Table 6). The treatment system for meeting effluent requirements would consist of an oxidation ditch, two clarifiers, chlorine disinfection and dechlorination**. Anticipated effluent quality is 15 mg/l BOD and 15 mg/l SS.

*Water use records show 87 gpcd not including school use.

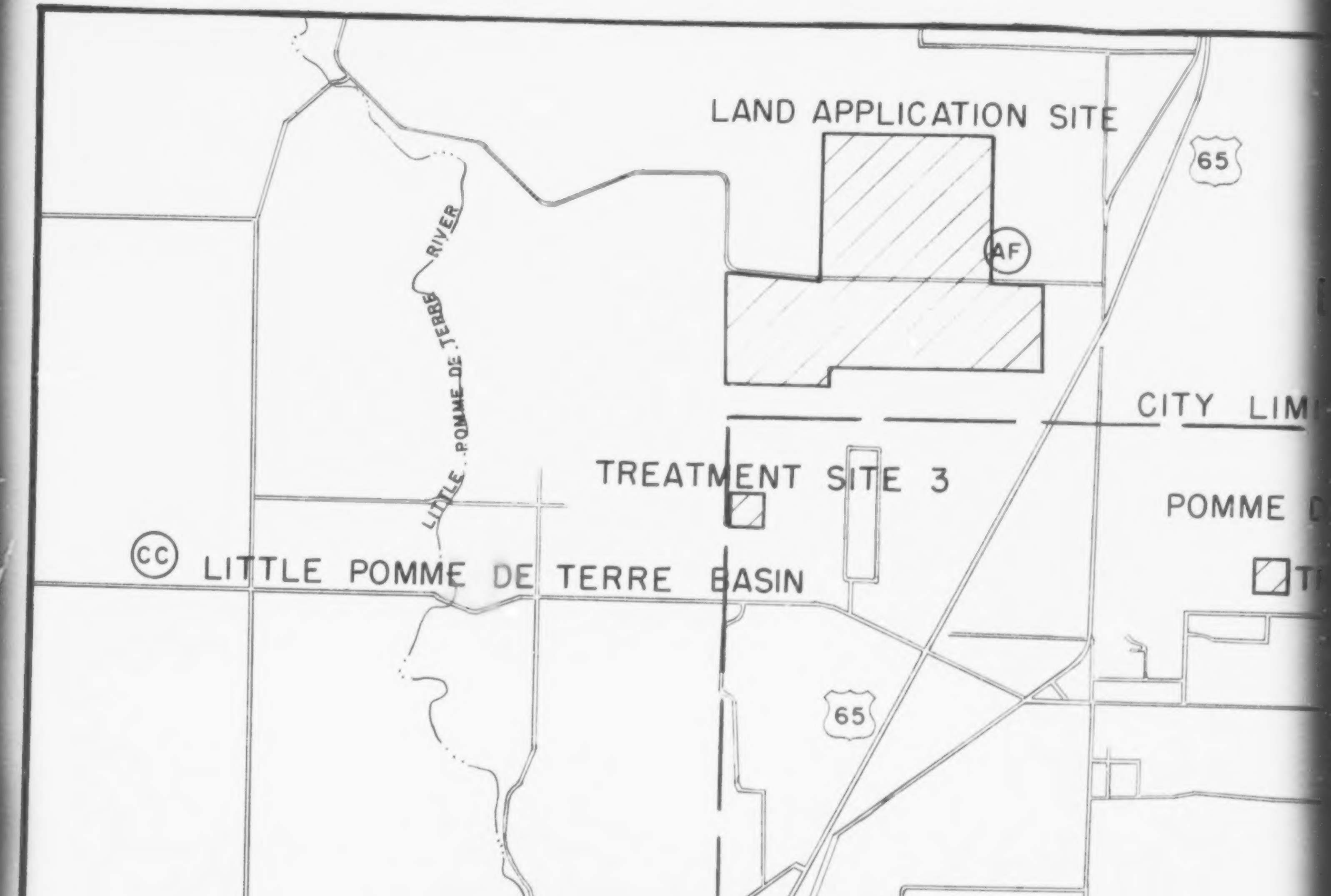
**Since the time of the Draft Facilities Plan, it has been determined that dechlorination will be required.

TABLE 36
FAIR GROVE SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Treatment Plant Site #1			
Pure Gravity	$3,824,188	$50,060	$396,016
Pure Pressure	2,988,771	72,685	403,737
Combination	3,358,626	54,380	381,766
Treatment Plant Site #2			
Pure Gravity	3,764,108	50,050	390,977
Pure Pressure	2,935,180	72,685	399,356
Combination	3,294,851	54,380	376,404
Treatment Plant Site #3			
Pure Gravity	3,646,313	50,060	381,060
Pure Pressure	2,935,562	72,685	399,552
Combination	3,183,277	54,380	367,062
Land Application			
Combination	3,412,360	100,280	443,074

Regional Pump Station to Strafford

Since the estimated annual capital cost of $116,282 for the pump station system was greater than the oxidation ditch treatment plant annual cost of $85,753, the regional pump station alternative was dropped from further consideration.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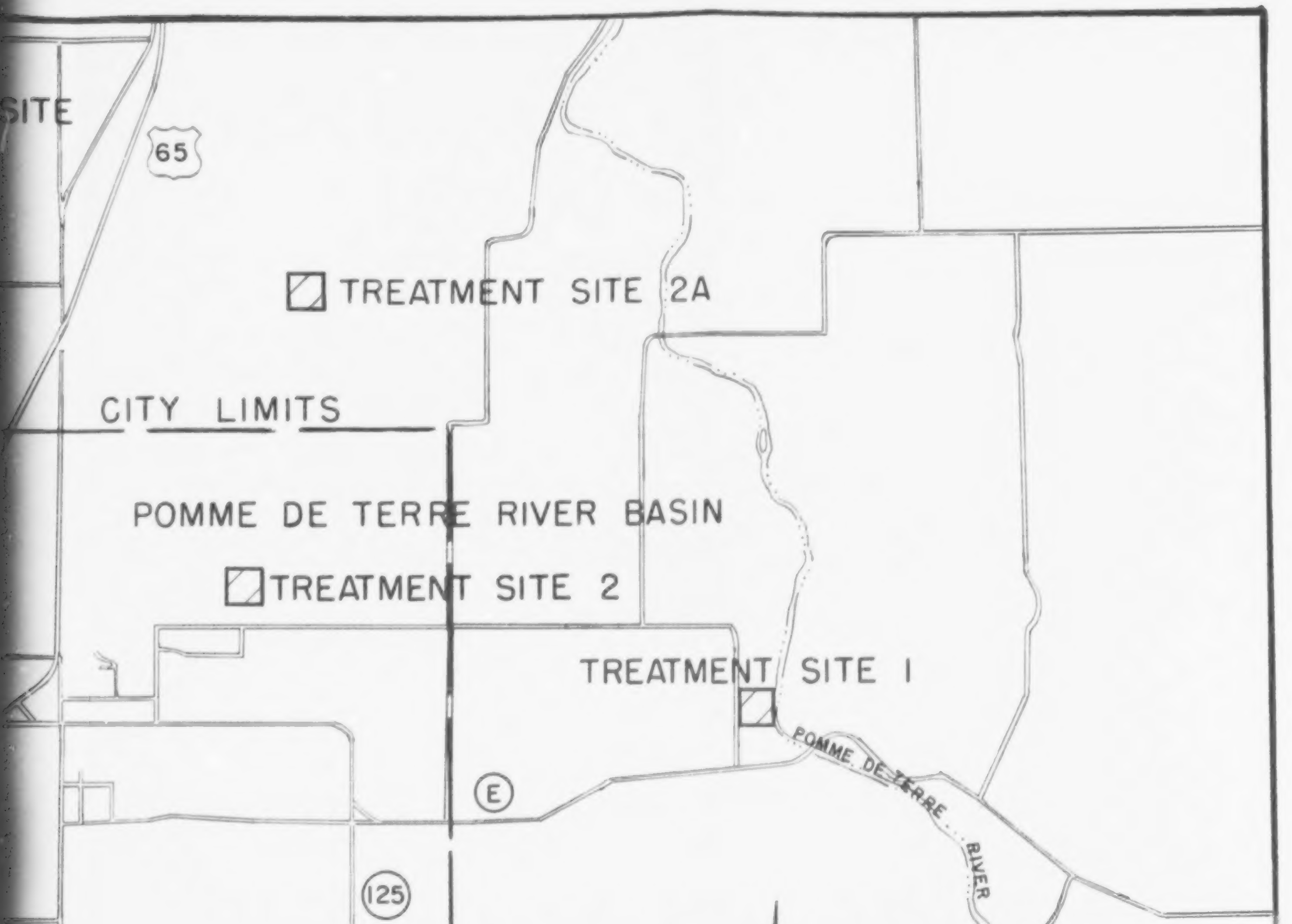
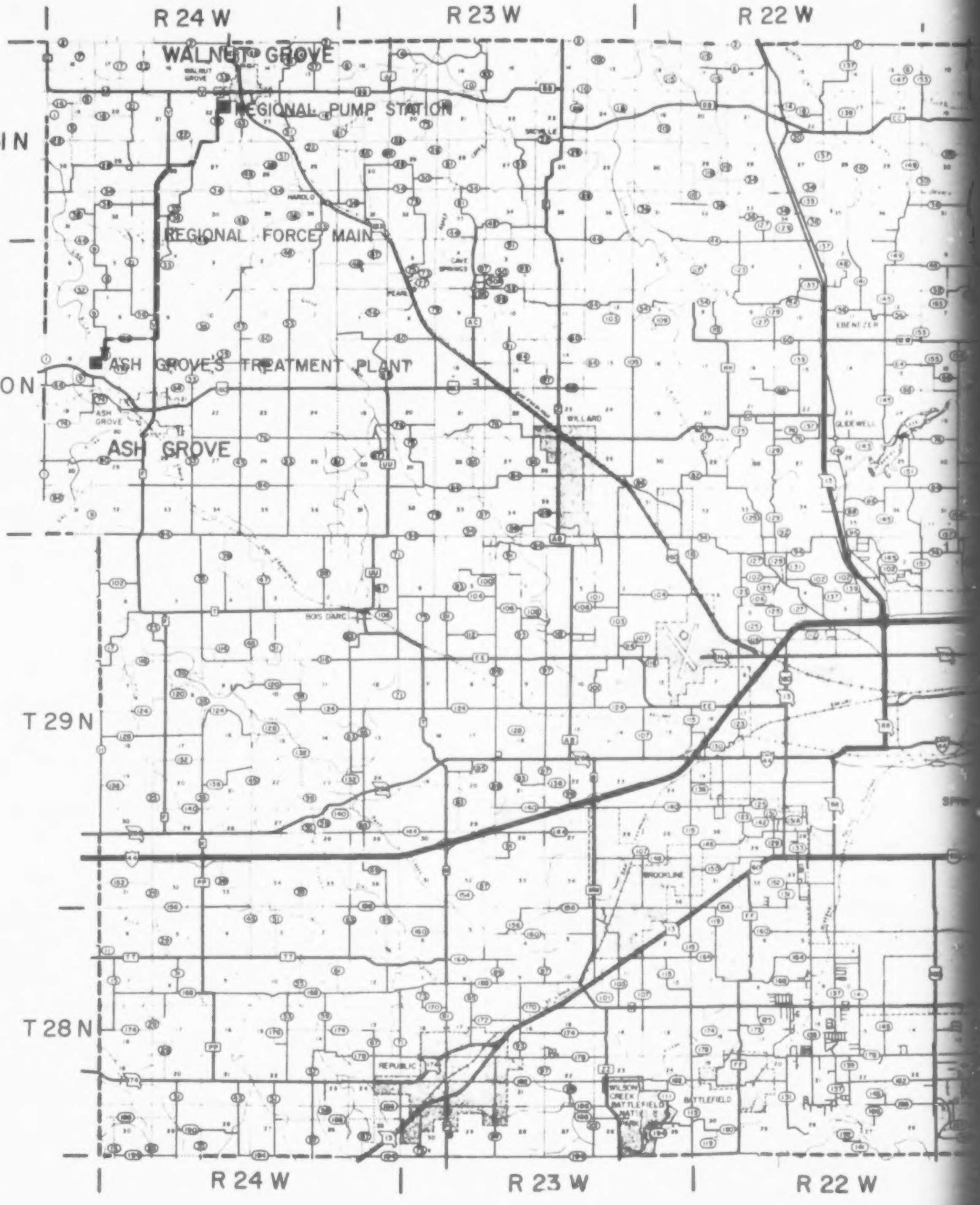


DEIS FIGURE 39

GREENE COUNTY SEWER DISTRICT
FAIR GROVE, MISSOURI SUBAREA
PLANNING AREA & TREATMENT SITES
FIGURE 1



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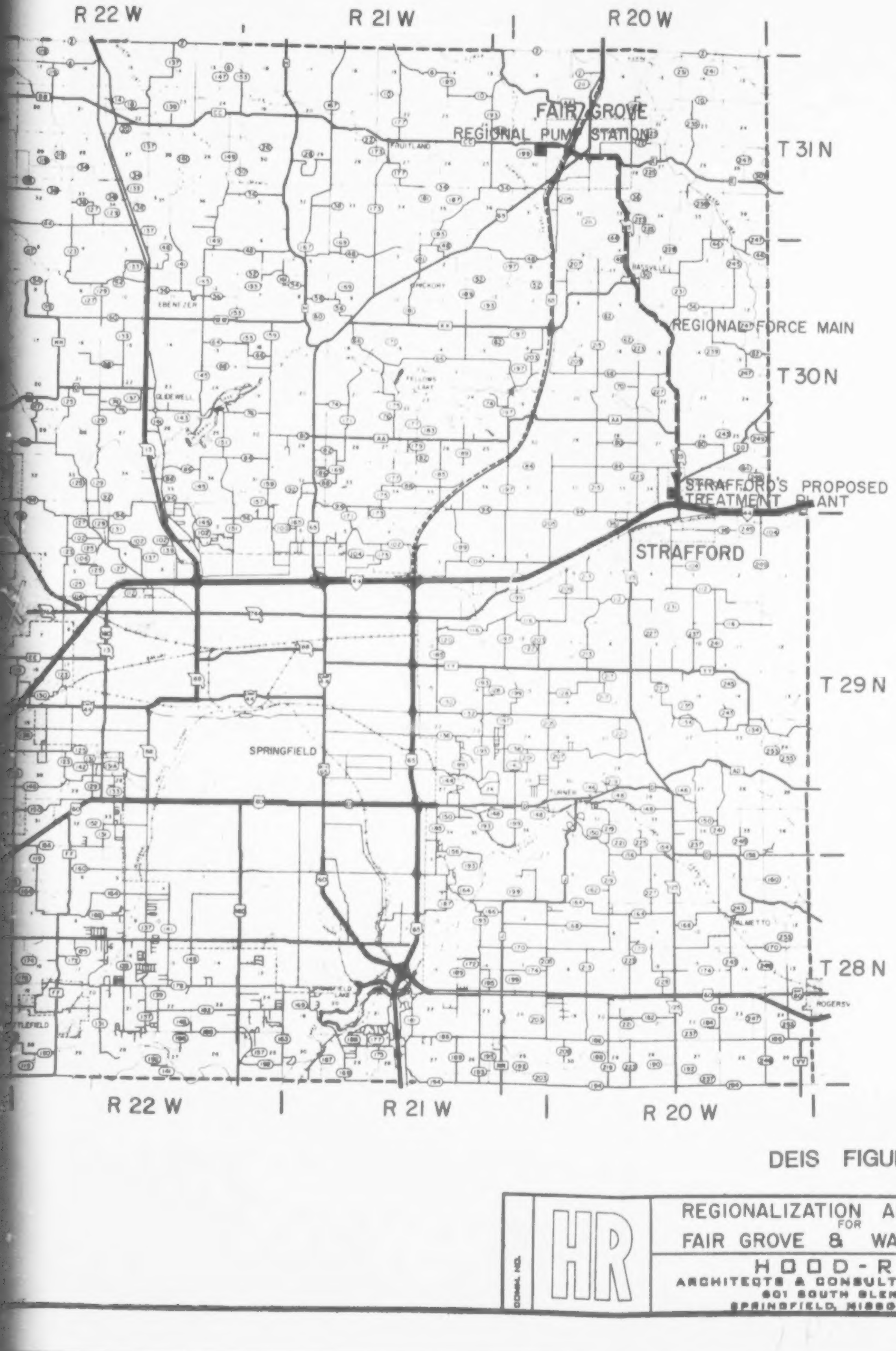

DEIS FIGURE 40

REGIONALIZATION ALTERNATIVES FOR FAIR GROVE & WALNUT GROVE

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ARCHITECTS & CONSULTING ENGINEERS
601 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

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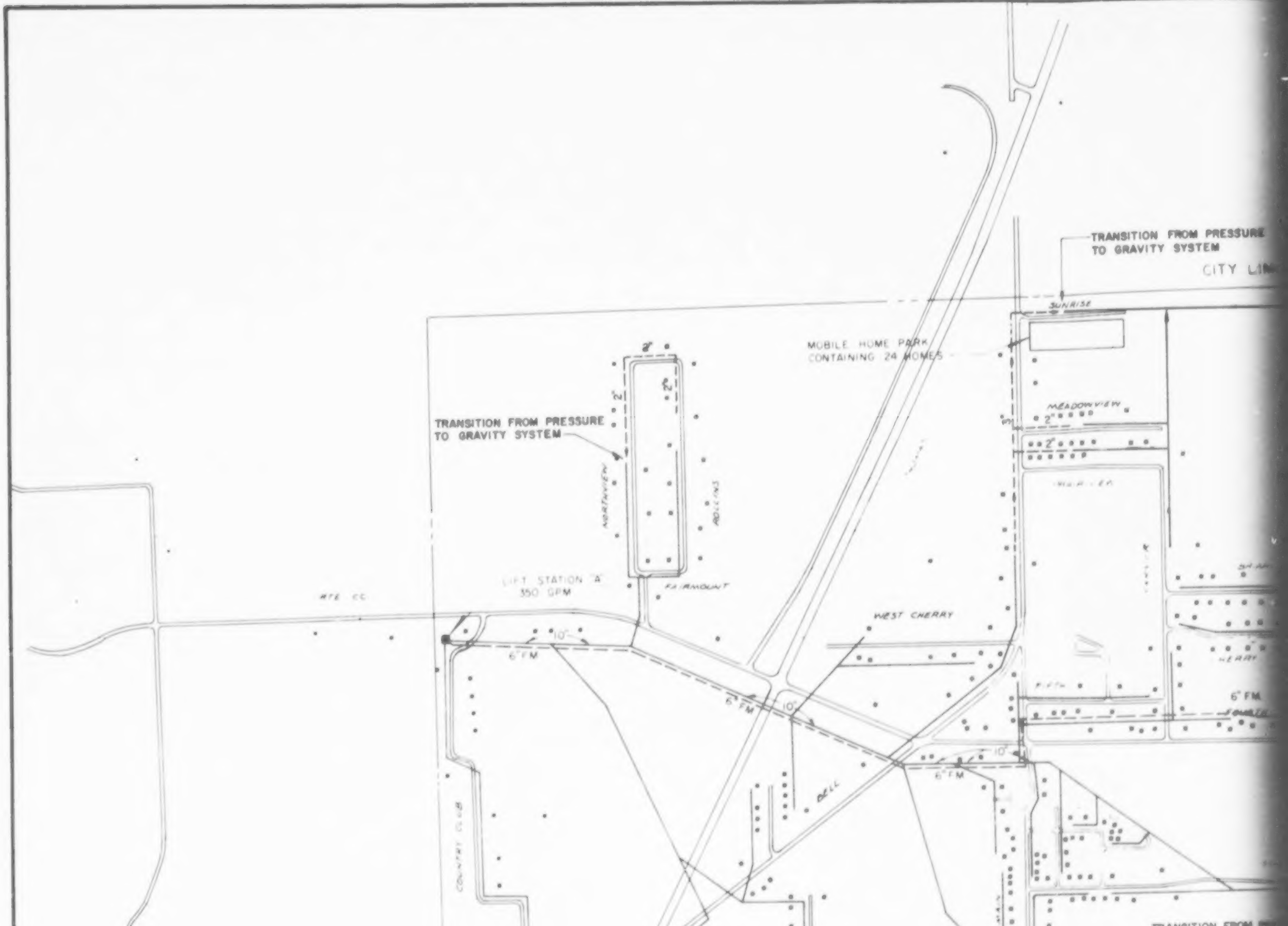

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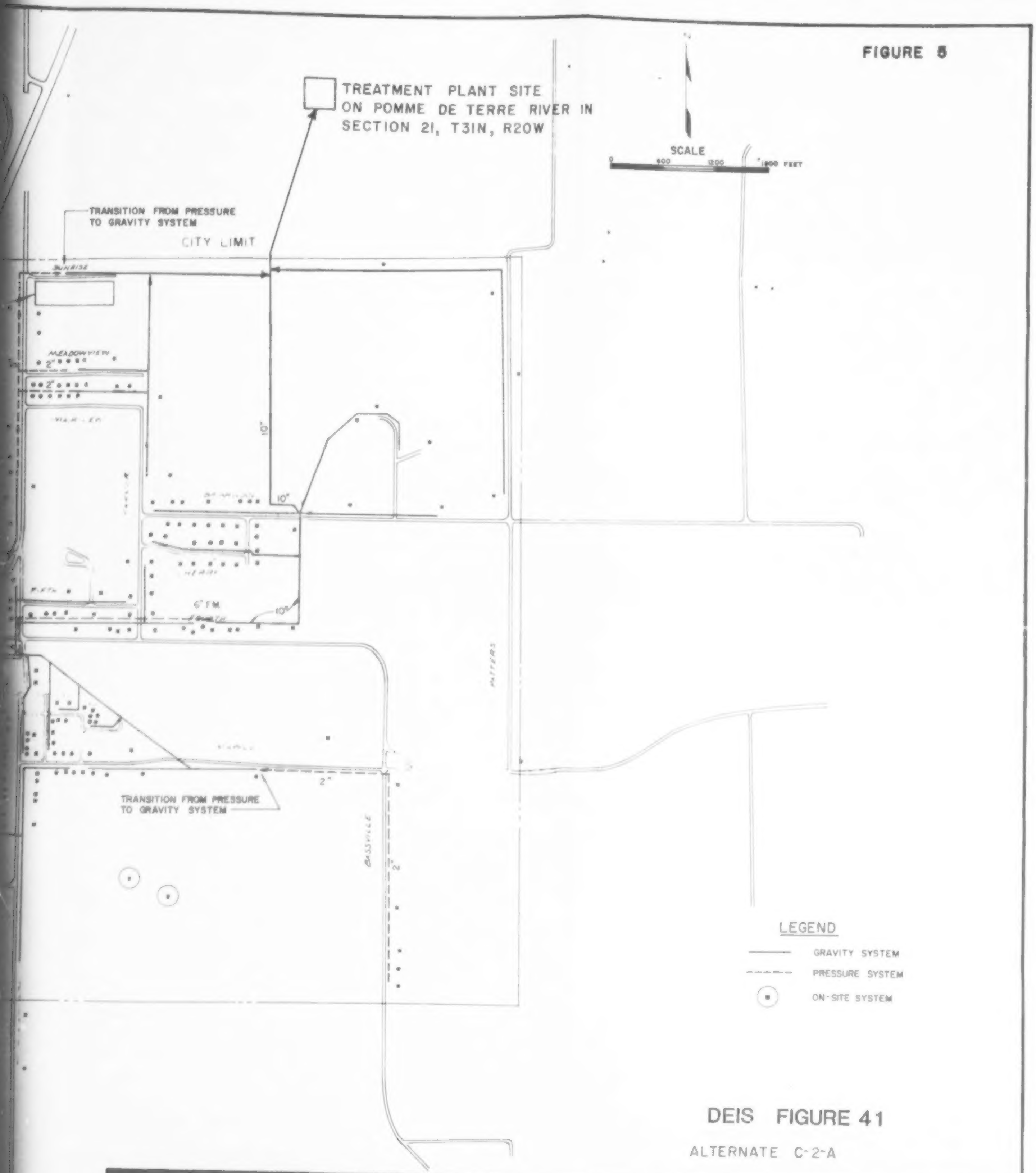
FIGURE 5



DEIS FIGURE 41

ALTERNATE C-2-A

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ASSOCIATES, INC.
ARCHITECTS & ENGINEERS
P.O. BOX 111 405/341-1114
EDMOND, OKLA. 73034

HR

COMBINATION SYSTEM
FAIR GROVE, MISSOURI

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

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3. Pomme de Terre River Tributary Treatment Plant, Site #2A (Proposed in Draft Facilities Plan)

The receiving stream is gaining, and effluent requirements and treatment are the same as for Site #1, except dechlorination may not be required. A combination gravity and pressure sewer system will serve most of the subarea, although a few on-site systems will remain (see Figure 41). The total capital cost of the project is estimated in the Draft Facilities Plan at $1,208,800 with a $17,000 annual O&M cost. In order to locate the treatment plant away from other development, the proposed treatment plant Site #2A has been changed from Site #2 considered earlier. Site #2A is now about one-half mile downstream (north) of the site proposed earlier in the Draft Facilities Plan.

4. Little Pomme de Terre River, Site #3, Treatment Plant

The receiving stream is gaining, and effluent requirements and treatment are the same as at Site Nos. 1 and 2A. Lagoon systems would be geologically acceptable at this site but were found to be higher in cost than the oxidation ditch system.

5. Regional Pump Station to Strafford

A pump station and approximately 58,000 feet of eight-inch force main would be used to transport wastewater to Strafford. This alternative would be possible only if a central system for the Strafford subarea is constructed. Chlorination would be provided at the pump station to help prevent the wastewater from becoming septic. The capital cost for the regional pump station system without considering incremental treatment costs at Strafford is higher than treatment plant alternatives. Therefore, this alternative is not further considered.

6. Land Application

A 0.53 acre aerated lagoon and center pivot spray irrigation system would be provided. A 12.6 acre sealed storage basin with 5½ months capacity would hold the lagoon effluent during the winter. Monitoring wells and fencing are provided. At a low application rate of 15 inches per year because of soil limitations, 223 acres are required for the application site. Costs include land purchase for the lagoon

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and storage basin, but application would be on private land. Land application is not cost-effective because of the soils limitations, storage requirements and related high costs.

E. REPUBLIC SUBAREA

The Republic subarea is presently served by both central and individual on-site wastewater systems. The City of Republic sewage collection and treatment system serves over 90 percent of the incorporated area, and 4,100 of the total population of 4,485. A small treatment facility serves The Willows, a subdivision About 445 people in the unincorporated subarea use individual systems. (Portions of the unincorporated subarea are in Brookline township as well as Republic township.)

Planning for the subarea is based upon existing and projected population as follows:

	Population Equivalent (PE)		
	1980	1995	2005
Republic Residents	4,485	7,597	9,658
Unincorporated Residents	445	534	606
Non-Resident Students	246 (985)*	273 (1092)*	296 (1182)*
Projected Industrial	--	813	1,026
Total	5,176	9,217	11,586

* Number of students

Based on current water use of 80 gpcd, average dry weather flows in 1980, 1995, and 2005 are 0.414 MGD, 0.737 MGD, and 0.927 MGD, respectively.

The existing City of Republic treatment facility does not consistently meet secondary treatment requirements. In addition, the receiving stream, Dry Branch of Pickerel Creek, has been found to be losing, so any expanded facilities at the existing site must meet losing stream requirements. The projected wasteloads will exceed the capacity of many existing plant components:

Component	Capacity (PE)
Blowers	4,670 - contact stabilization
	3,503 - extended aeration
Aeration Chamber	13,189 - contact stabilization
	3,957 - extended aeration
Clarifier	5,478
Sludge Digester	10,667
Lagoon	5,800 - treated sewage applied
	1,170 - raw sewage applied
Disinfection	12,774

Investigations following the 1968 collapse of Republic's southeast lagoon identified several sinkholes in the vicinity of the northwest lagoon. Improvements to the Republic system are a very high priority because of existing problems of discharging inadequately treated effluent to a losing stream and the potential for catastrophic collapse of the northwest lagoon. Excessive infiltration and inflow during wet weather is also a serious problem.

Alternatives evaluated for the subarea (refer to Figure 42) are 1) no action, 2) a new treatment plant at the existing plant site with three alternate levels of system expansion and improvement, 3) a new regional treatment plant discharging to Shuyler Creek or McElhaney Branch and serving Republic, Battlefield, Brookline, 4) a regional pump station and force main to Springfield's Wilson's Creek Interceptor and the Southwest Treatment Plant, and 5) land application. Total project, annual O&M, and total annual costs of the alternatives are presented in Table 37.

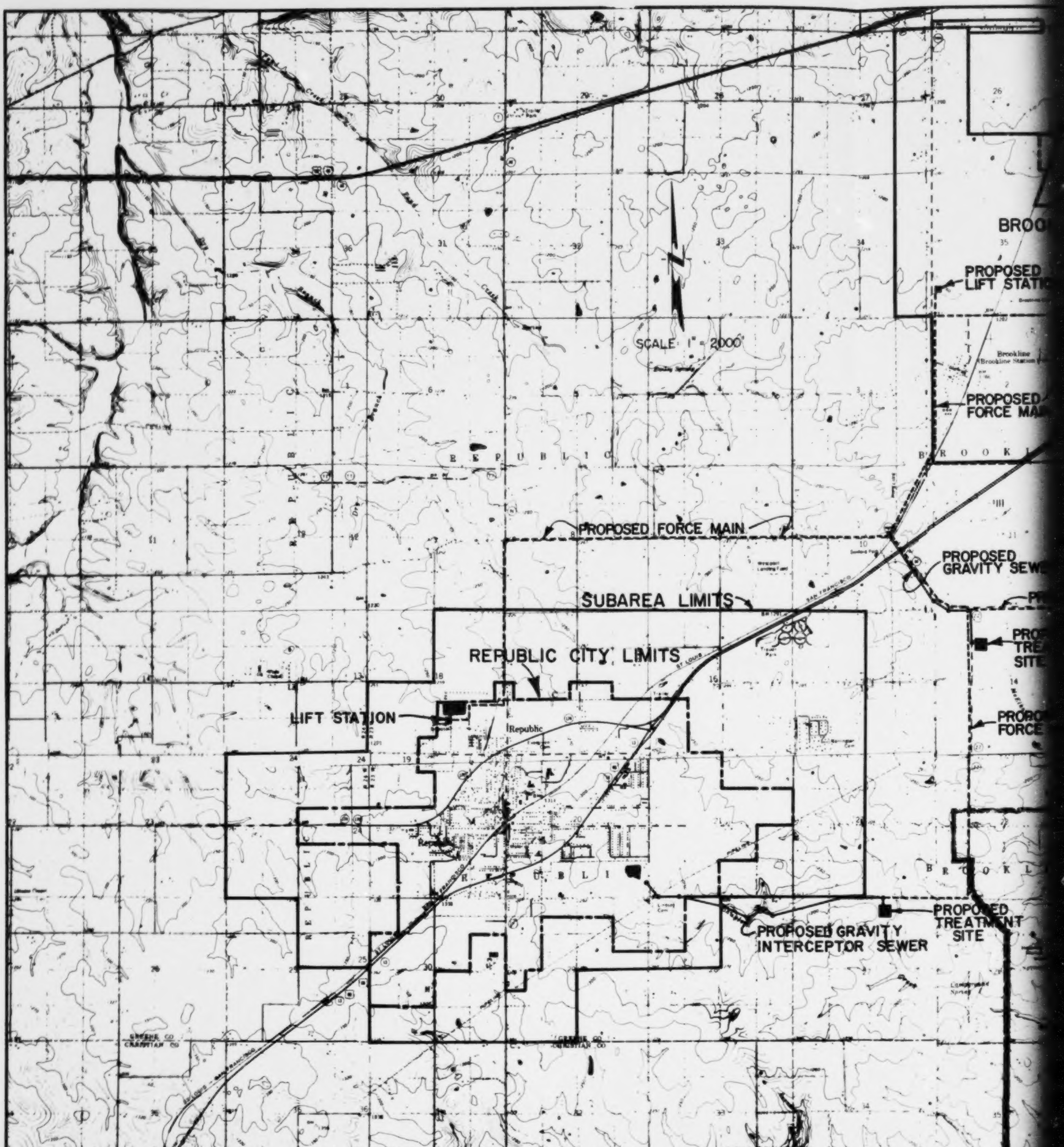
1. No Action

No action alternatives in the Republic subarea include the possibilities of local action without federal funding assistance or no local action. Improvements without funding assistance would likely be limited greatly by resulting customer costs. If a minimum project of a new treatment plant and improvements to the existing collection system is undertaken, problems with existing septic tank systems and future unsewered development would remain. If no local action is taken, additional problems with sewer backups, high collection system maintenance costs, and enforcement actions for discharge permit

TABLE 37
REPUBLIC SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Treatment Alternatives - Existing Site			
Orbal Activated Sludge Plant	$1,602,700	$ 70,487	$218,887
Oxidation Ditch Plant	1,688,100	72,909	227,709
Regional Plant			
Shuyler Creek Site	2,804,485	63,000	315,433
Regional Pump Station to Springfield	2,547,250	284,032*	506,446
Land Application - Without Land Cost	8,060,150	282,215	1,065,449
Alternative Projects Using Existing Treatment Site			
Minimum Project	2,678,900	109,011	--
(Plant.	1,172,700)		
(Sewer Rehab.	261,700)		
(Lift Stations.	573,500)		
(Engr., Insp., Adm. . . .	671,000)		
City Limit Project	3,708,206	101,637	--
(Plant.	1,172,700)		
(Sewer Rehab.	261,700)		
(Expand & Upgrade	1,464,606)		
(Engr., Insp., Adm. . . .	809,200)		
Subarea Project	9,982,482	137,060	--
(Plant.	1,172,700)		
(Sewer Rehab.	261,700)		
(Expand & Upgrade	6,764,682)		
(Engr., Insp., Adm. . . .	1,783,400)		

* Includes estimated treatment cost.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LIFT STATION
Republic
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GREENE CO
CHRISTIAN CO
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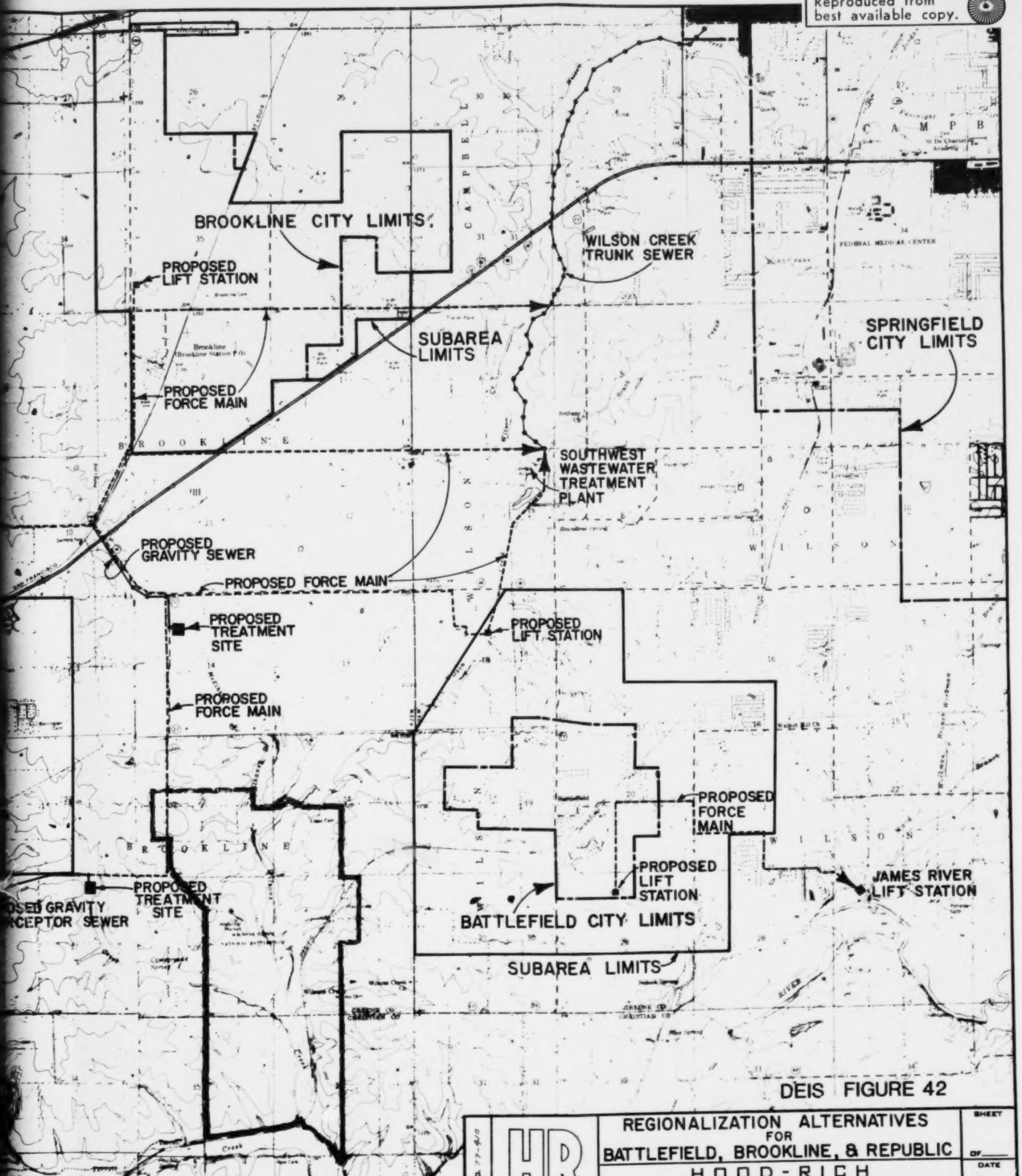

DEIS FIGURE 42

COMM. NO. 77-910

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REGIONALIZATION ALTERNATIVES
FOR
BATTLEFIELD, BROOKLINE, & REPUBLIC

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

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violations would likely occur. The City of Republic and Greene County may control and manage on-site systems to varying degrees.

2. New Treatment Plant at Existing Dry Branch Plant Site (Proposed in Draft Facilities Plan)

A new treatment plant at the existing site and three alternate levels of system expansion and improvement are considered. Dry Branch is a tributary to Pickerel Creek and both are classified as losing streams. Losing stream effluent standards apply as given in Table 6. The treatment system for meeting effluent requirements would consist of orbal activated sludge aeration, two clarifiers, gravity sand filtration, and chlorine disinfection. The existing plant would be converted to a sludge holding tank, and sludge drying beds would be added. Effluent quality of 1 to 10 mg/l BOD and 1 to 10 mg/l SS can be expected.

a. Upgrading Existing System. The "minimum" project consists of a new treatment plant, sewer line rehabilitation, and upgrading existing lift stations.

b. Upgrading and Expanding System Within City Limits. (Proposed in Draft Facilities Plan) The "city limit" project consists of a new treatment plant, sewer line rehabilitation, consolidating and upgrading existing lift stations, and expanding the collection system within the city limits. Six new lift stations would be constructed and four existing stations expanded or rebuilt as part of this program.

The Draft Facilities Plan proposed a new treatment facility to serve the year 2005 waste load, rehabilitation of existing collection sewers to reduce peak flows to 4.71 MGD construction of new sewers and lift stations to serve the entire city limits area, and upgrading of existing lift stations. The total cost of these improvements is estimated at $3,472,785. Estimated annual O&M costs are $53,681 for treatment, and $47,957 for collection, yielding a total of $101,638.

c. Upgrading and Expanding System for Entire Subarea. The "subarea" project consists of a new treatment plant, sewer line rehabilitation, consolidating and upgrading existing lift stations, and expanding the collection system within the entire subarea. Eleven new lift stations would be included, and eleven of the existing lift stations would be enlarged or rebuilt.

3. Shuyler Creek or McElhaney Branch Regional Treatment Plant

A regional treatment facility to serve Battlefield and Brookline as well as the Republic subarea was considered. Alternative sites are on Shuyler Creek and on McElhaney Branch. Shuyler Creek is a losing stream, and losing stream effluent requirements apply (see Table 6). The McElhaney Branch site is within one mile of Wilsons Creek, which is a losing stream; therefore, losing stream effluent requirements also apply at this site. The treatment system for meeting the effluent requirements would consist of orbal activated sludge aeration, two clarifiers, gravity filtration, and chlorine disinfection. An aerated sludge holding tank would be provided. Average 20-year design flow of the plant is 1.58 MGD with the Republic subarea share being 60 percent of the BOD and average flow. Relative costs for the Shuyler Creek plant were much higher than for a plant on the Dry Branch. Costs for the McElhaney Branch would be similar to the Shuyler Creek site, although detailed estimates were not prepared.

4. Regional Pump Station to Springfield

A pump station and about 74,000 feet of 16-inch force main would be installed to deliver raw wastewater to Springfield's Wilsons Creek interceptor and the Southwest Treatment Plant. Two electric generators would be provided in case of power outage. Twin force mains are provided for reliability and to handle wet weather flows. The system would serve only the Republic subarea.

5. Land Application

Preliminary treatment with the existing contact stabilization plant and a center pivot spray irrigation system would be provided. A 96-acre sealed storage basin with 5½ months capacity would hold the plant effluent during the winter. Monitoring wells and fencing would be provided. At a low application rate of 15 inches per year because of soil limitations, 1124 acres are required for the application site. Costs include land purchase for the lagoon and storage basin, but application would be on private land. Several sinkholes were also noted and would restrict both application and holding basin sites. These limitations and related high costs make the land application alternative unfeasible.

F. STRAFFORD SUBAREA

The Strafford subarea is presently served by individual wastewater disposal systems and a small package plant and lagoon serving a truck stop. Planning for the subarea is based on 1980 and projected design year population as follows:

	Population Equivalent	
	1980	2005
Strafford Residents	1,121	2,682
Strafford Businesses	--	268
Unincorporated Residents	98	504
Non-Resident Students	171 (684)*	222 (890)*
Total	1,390	3,676

* Number of students

The design population equivalent is thus about 3,680, and the average dry weather design flow at 75 gpcd is 0.276 mgd.

Alternative plans for the subarea (refer to Figures 43, 44, and 45) are 1) no action (or improvement of existing systems), 2) a treatment plant discharging to Pierson Creek, 3) a treatment plant discharging to Davis Creek, 4) a treatment plant discharging to Broad Creek, 5) and 6) a treatment plant discharging to the South Fork of the Pomme de Terre River at one of two sites, 7) a treatment plant discharging to the Little Sac River, 8) a regional pump station to the Springfield sewer system and the Southwest Plant, 9) a gravity sewer along Pierson Creek to connect to Springfield's Pierson Creek interceptor and the Southwest Plant, and 10) land application. For the central collection and treatment systems, gravity, pressure, and combination collection and on-site system alternatives were considered. The combination system has gravity and pressure system areas with some on-site facilities. Cluster system alternatives were dropped because of unsuitable soils in the Strafford area.

Total project, annual O&M, and total annual costs for each alternative are presented in Table 38.

TABLE 38
STRAFFORD SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Pierson Creek Plant Combination	$4,195,100	$53,405	$482,885/435,600(c)
Davis Creek Plant(a) Combination	4,011,000	51,160	460,585/456,600(c)
Broad Creek Plant Combination	3,961,300	51,160	457,730/399,500(c)
South Fork Pomme De Terre Plant, Site #1 Combination	4,098,100	55,755	460,055/439,700(c)
South Fork Pomme de Terre Plant, Site #2(c) Combination	4,174,600	51,485	461,445/437,700(c)
Union 76 Site Combination	2,544,600(c)(d)	29,200(c)(d)	405,500(e)
Little Sac River Plant Combination	3,970,800	54,340	461,930/415,300(c)
Regional Pump Station to Springfield Southern System(f) Combination	3,546,200	64,875 to 87,050(b)	431,700 to/392,000(c) 453,875
Pierson Creek Sewer to Springfield Southwest System Combination	3,926,300	49,405 to 71,580(b)	445,815 to/422,800(c) 467,990
Land Application Combination	4,321,600	117,750	555,082/--

(a) Based upon gaining stream effluent requirements; since determined to be losing.

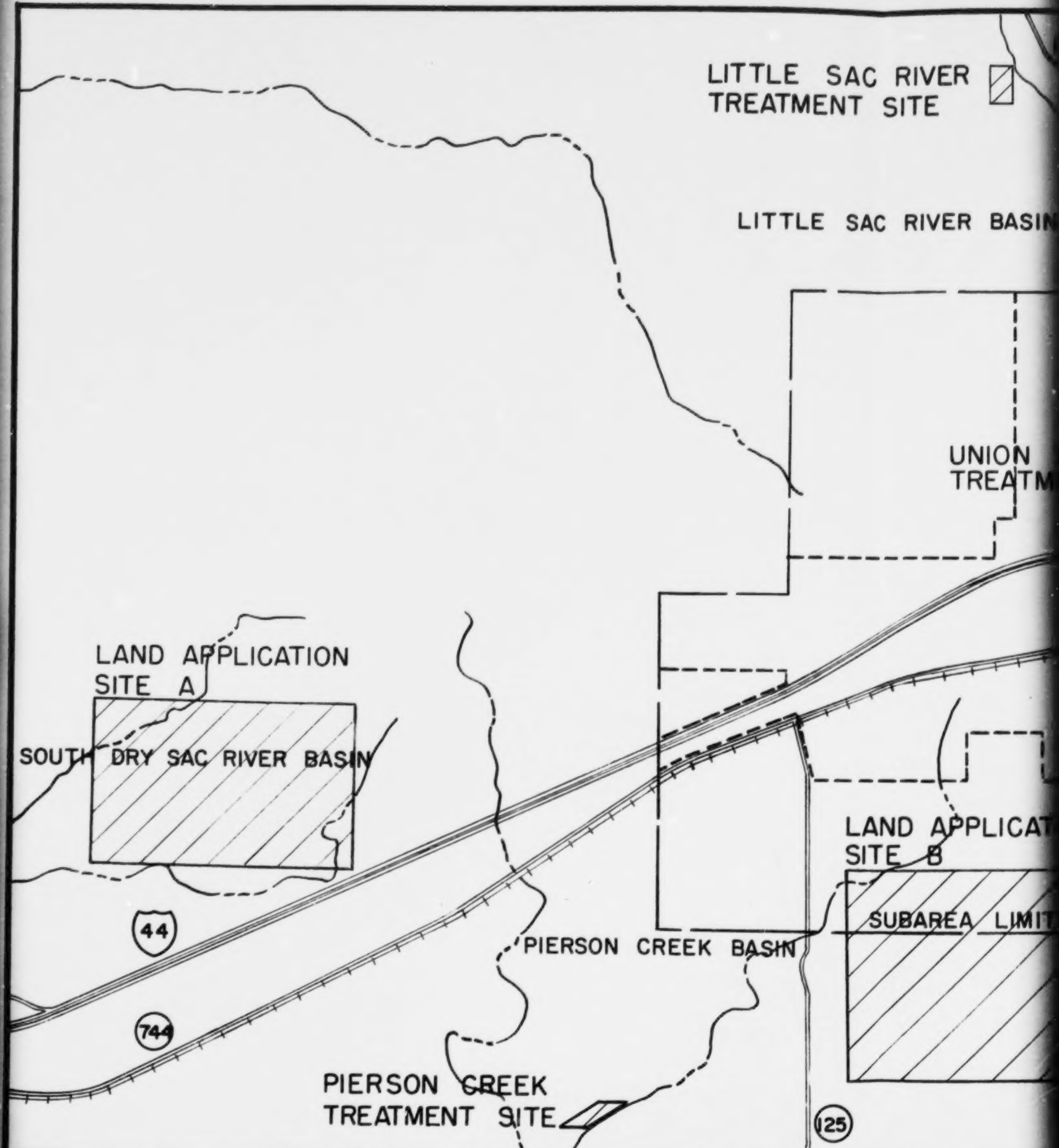
(b) Depending on treatment costs.

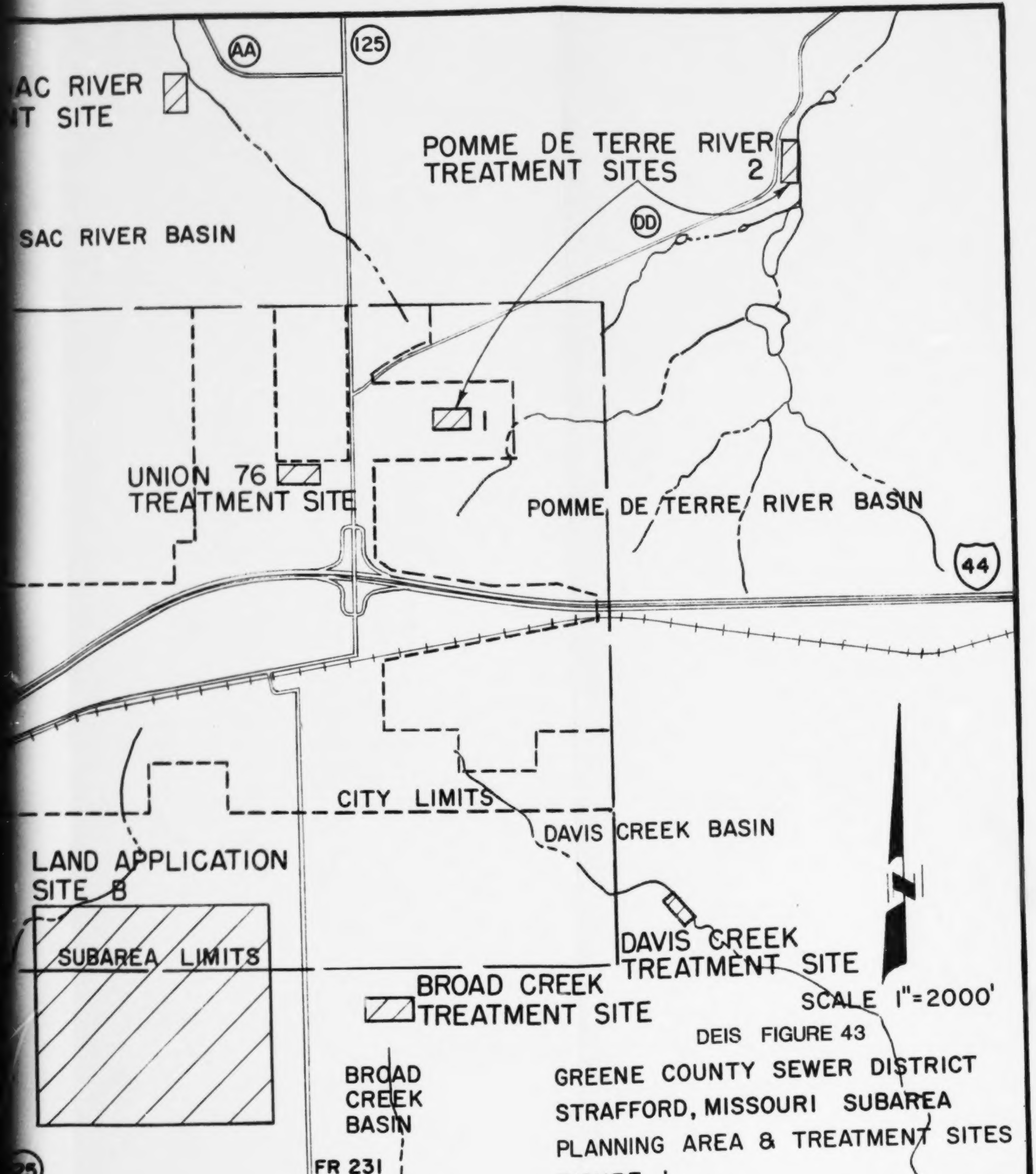
(c) From Draft Facilities Plan (1), as differentiated from the other figures presented which are from earlier preliminary facilities planning comparisons.

(d) Does not include chlorination and dechlorination.

(e) Includes chlorination and dechlorination.

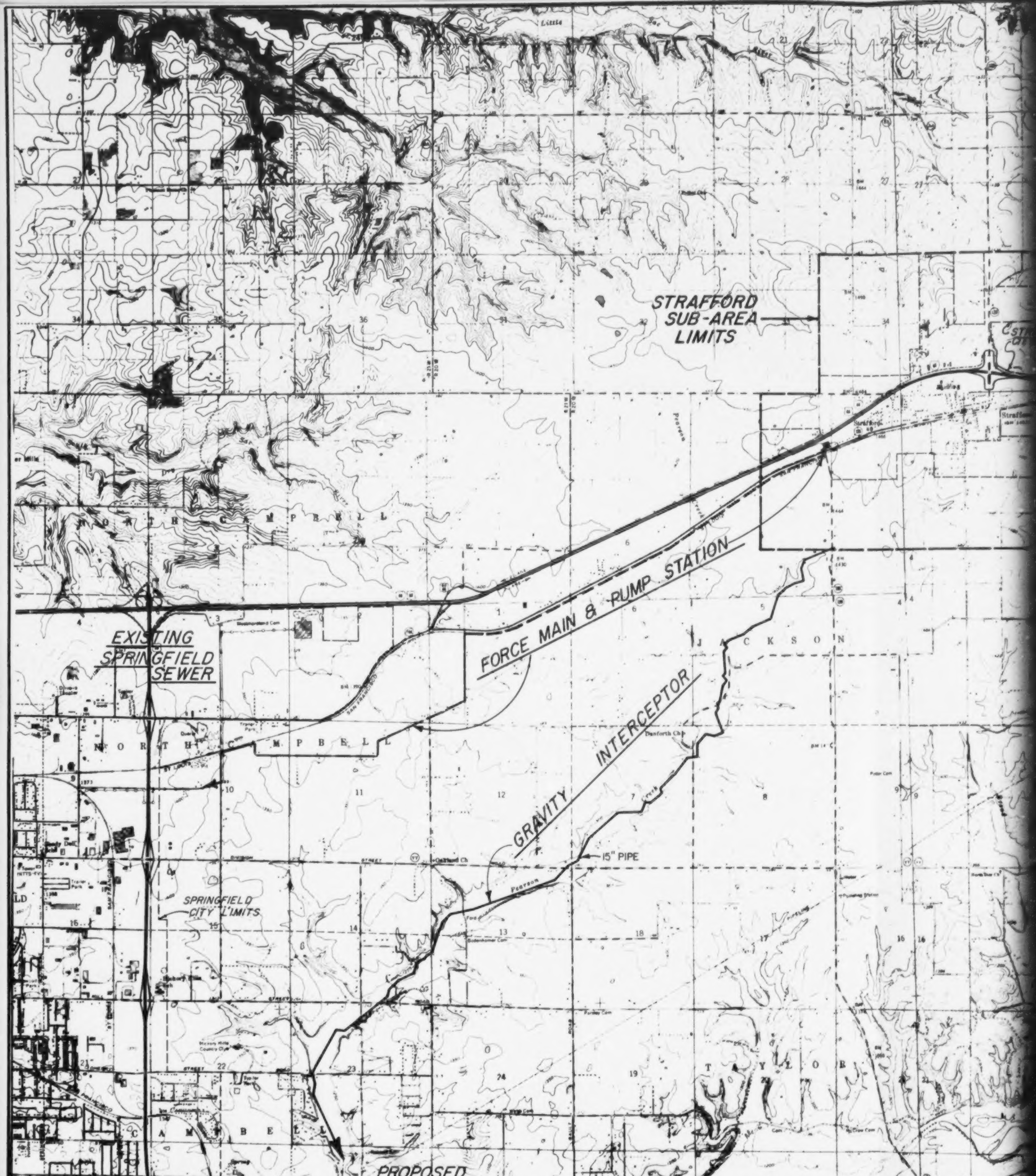
(f) Preliminary costs based on connection to Springfield northern system.


LITTLE SAC RIVER TREATMENT SITE
LITTLE SAC RIVER BASIN
UNION
TREATM
LAND APPLICATION SITE A
SOUTH DRY SAC RIVER BASIN
LAND APPLICAT
SITE B
SUBAREA LIMIT
44
PIERSON CREEK BASIN
744
PIERSON CREEK TREATMENT SITE
125



DEIS FIGURE 43

GREENE COUNTY SEWER DISTRICT
STRAFFORD, MISSOURI SUBAREA
PLANNING AREA & TREATMENT SITES
FIGURE 1


STRAFFORD SUB-AREA LIMITS
EXISTING SPRINGFIELD SEWER
FORCE MAIN & PUMP STATION
GRAVITY INTERCEPTOR
15" PIPE
SPRINGFIELD CITY LIMITS
PROPOSED PIERSON CREEK SPRINGFIELD SEWER
NORTH CAMPBELL
JACKSON
TAYLOR
CAMPBELL

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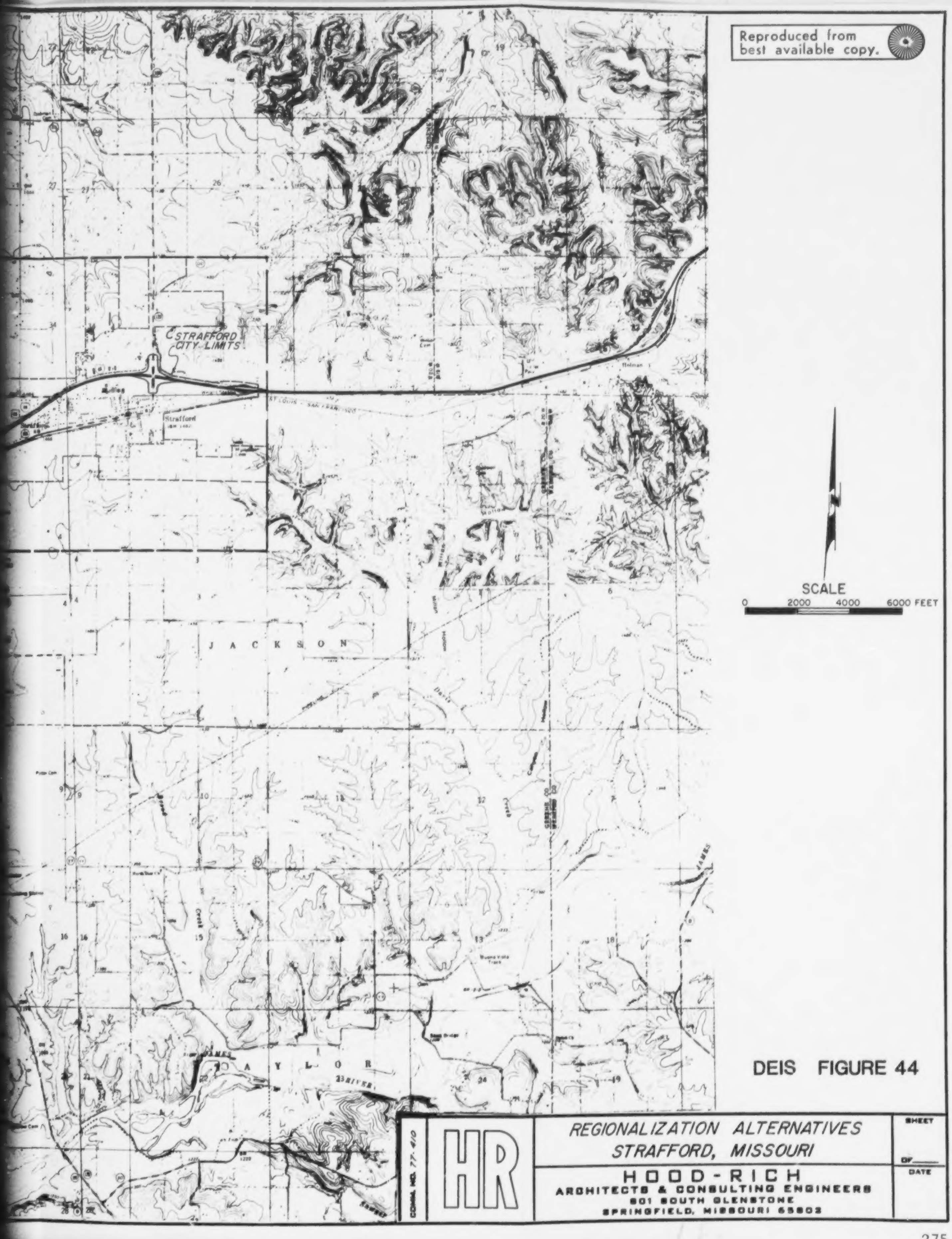


DEIS FIGURE 44

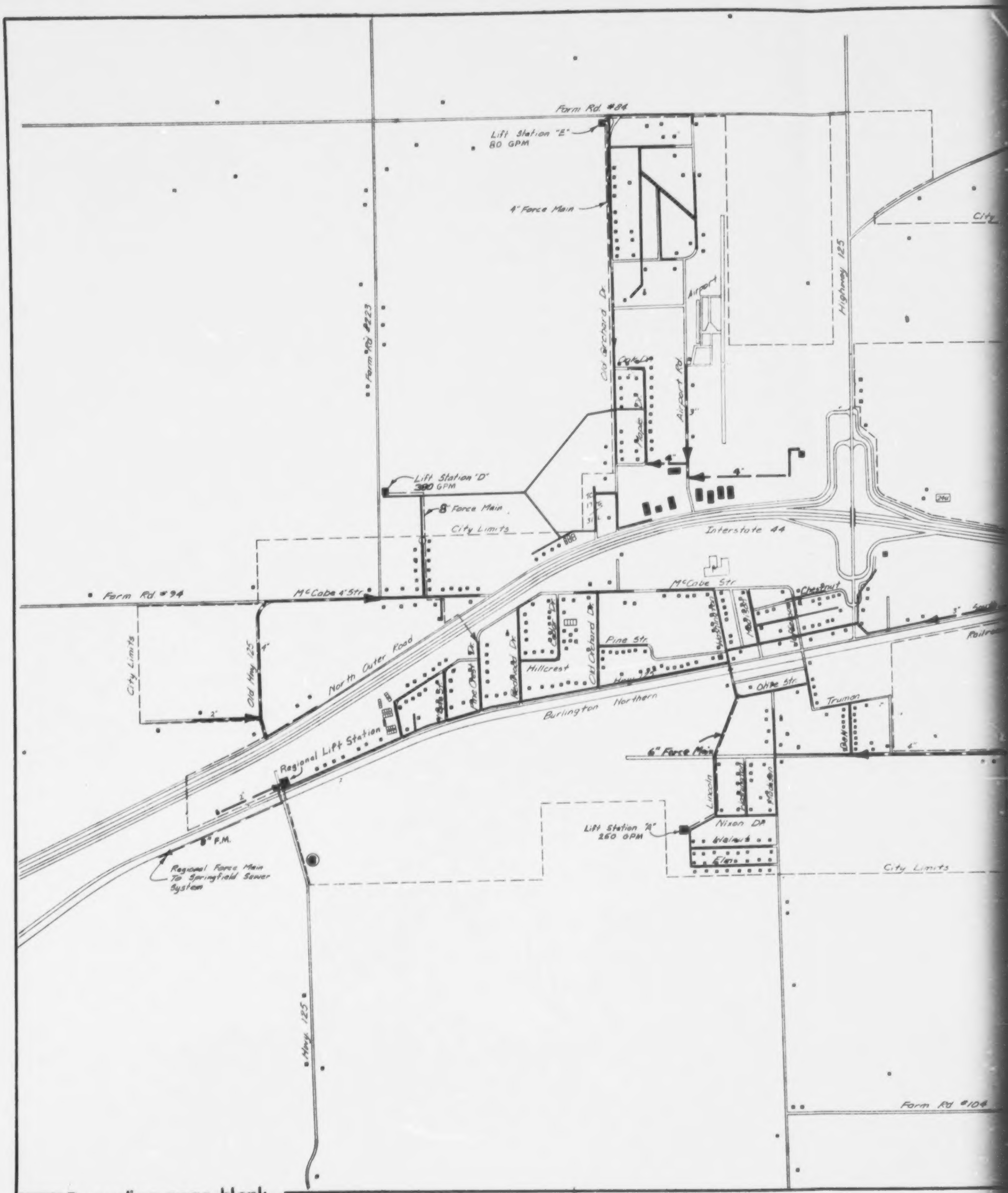
COMM. NO. 77-410

HR

REGIONALIZATION ALTERNATIVES
STRAFFORD, MISSOURI

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

SHEET
OF
DATE



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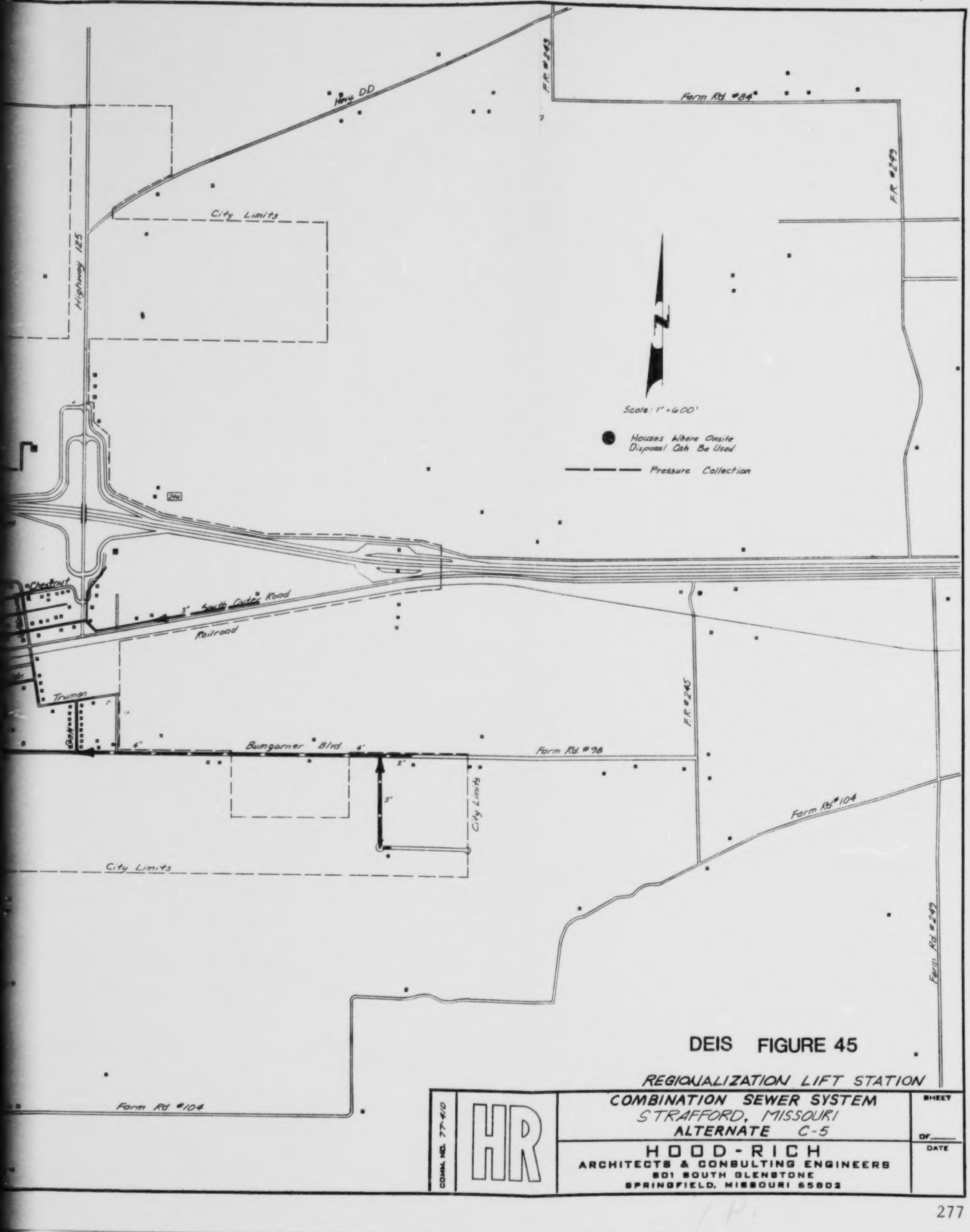

DEIS FIGURE 45

REGIONALIZATION LIFT STATION

COMBINATION SEWER SYSTEM
STRAFFORD, MISSOURI
ALTERNATE C-5

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

COMM. NO. 77-410

SHEET

OF

DATE

1. No Action

Without federal and state funding assistance, it is unlikely that any central collection and treatment system could be financed. No action alternatives mean continued use of existing septic tank and small treatment systems and installation of new ones. The City of Strafford and Greene County may control and manage on-site systems to varying degrees. Soil and geological conditions preclude the longer term acceptability of on-site systems in many areas.

2. Pierson Creek Treatment Plant

Pierson Creek is a losing stream and losing stream effluent requirements apply (refer to Table 6). The discharge location is approximately 7.8 miles above the confluence with the James River.

The treatment system for meeting effluent requirements would consist of an oxidation ditch, two clarifiers, gravity sand filtration, and chlorine disinfection. Anticipated effluent quality is 2 to 10 mg/l BOD and 1 to 10 mg/l SS.

3. Davis Creek Treatment Plant

Davis Creek was initially indicated to be a gaining stream below the discharge point but later reports showed it to be losing. The discharge location is approximately 3.6 miles upstream of the confluence with the James River. The Davis Creek confluence is approximately 10.5 miles upstream of the Pierson Creek confluence with the James River.

The treatment system for meeting gaining stream effluent requirements would have consisted of an oxidation ditch and two clarifiers. Effluent quality of 15 mg/l BOD and 15 mg/l SS is expected. Filtration and disinfection would need to be added to meet losing stream requirements.

4. Broad Creek Treatment Plant

Broad Creek is a losing stream with losing stream effluent requirements. The discharge location is approximately 4.0 miles upstream of the confluence with the James River. The Broad Creek confluence is approximately 7.5 miles upstream of the Pierson Creek confluence with the James River.

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The treatment system for meeting effluent requirements would consist of an oxidation ditch, two clarifiers, gravity sand filtration, and chlorine disinfection. Effluent quality of 2 to 10 mg/l BOD and 1 to 10 mg/l SS is expected.

5. South Fork Pomme De Terre Treatment Plant, Site #1

The South Fork Pomme De Terre River is a gaining stream in the vicinity of Site #1 and gaining stream effluent requirements apply. The discharge is about 6.5 miles upstream of the confluence with the Pomme de Terre River and 1.2 miles upstream of the first of two small reservoirs. Because of recreational use of the reservoirs, fecal coliform in the effluent would be limited to 200 per 100 ml.

The treatment system for meeting effluent requirements would consist of an oxidation ditch and two clarifiers, plus chlorine disinfection. Effluent quality of 15 mg/l BOD, 15 mg/l SS and less than 200 fecal coliform/100 ml is anticipated.

6. South Fork Pomme De Terre Treatment Plant, Site #2 and "Union 76" Site*

The South Fork Pomme de Terre River in the vicinity of Site #2 is a gaining stream. Discharge is below the reservoirs noted for Site #1. Effluent requirements and treatment would be the same as for Site #1. (Fecal coliform limits and associated disinfection were not included in the Draft Facilities Plan, but MDNR has since advised that disinfection would be required because of whole body contact recreation, and dechlorination would be required to protect aquatic life.) With a treatment plant at the Union 76 site, effluent would be piped to the same discharge point as for Site #2, and the same treatment and effluent requirements apply. The Union 76 Site alternative was proposed in the Draft Facilities Plan at an estimated total capital cost of $3,834,200 to serve the entire subarea and designed for the year 2005 waste load. Annual O&M costs are estimated at $47,125 and total annual costs at $398,100 (increases to $405,500 to include chlorination and dechlorination).

---

*Proposed in Draft Facilites Plan but subsequently changed to pumping to Springfield southern system.

7. Little Sac River Treatment Plant

Gaining stream effluent requirements apply to the Little Sac River. The discharge point is approximately 3.6 miles upstream of Fellows Lake. Since Fellows Lake is used for recreation* and is a drinking water supply source, fecal coliform in the effluent would be limited to 200 per 100 ml.

The treatment system for meeting effluent requirements would consist of an oxidation ditch and two clarifiers plus chlorine disinfection. Effluent quality of 15 mg/l BOD, 15 mg/l SS and less than 200 fecal coliform/100 ml is anticipated.

8. Pumping to Springfield Southern System (Proposed)

A pump station and approximately 27,000 ft of 8" force main would be used to transport wastewater to the Springfield southern system near the quarry at Highway 65. (This has been changed from preliminary planning to pump to Springfield's northern system, since additional capacity for Springfield's planned South Dry Sac interceptor and Northwest Treatment Plant would have been required.) Chlorination of the raw sewage would be provided to combat septic conditions.

9. Pierson Creek Gravity Sewer to Springfield Southern System

Approximately 36,000 ft of gravity sewer would transport wastewater to Springfield's proposed Pierson Creek trunk sewer and the Southwest Plant. Chlorination of the raw sewage would be provided to combat septic conditions.

10. Land Application

A 0.6 acre aerated lagoon and center pivot spray irrigation system would be provided. A 14.0 acre sealed storage basin with 5½ months capacity would hold the lagoon effluent during the winter. Monitoring wells and fencing are provided. At a low application rate of 15 inches per year because of soil limitations, 247 acres are required for the application site. Costs include land purchase for the lagoon and storage basin, but application would be on private land. Land application is not cost-effective because of the soils limitations, storage requirements, and related high costs.

---

*Springfield City Utilities does not allow whole body contact recreation at Fellows Lake.

G. WALNUT GROVE SUBAREA

The Walnut Grove subarea is presently served by individual wastewater disposal systems. Planning for the subarea is based upon existing and projected design year population as follows:

	Population Equivalent			
	1980		2005	
Walnut Grove Residents	504		670	
Non-Resident Students	75	(300)	90	(362)*
Total	579		760	

* Number of students

At the design population equivalent of 760, the average dry weather design flow at 100 gpcd (existing water use of 220 gpcd appears unreasonably high) is 0.076 MGD.

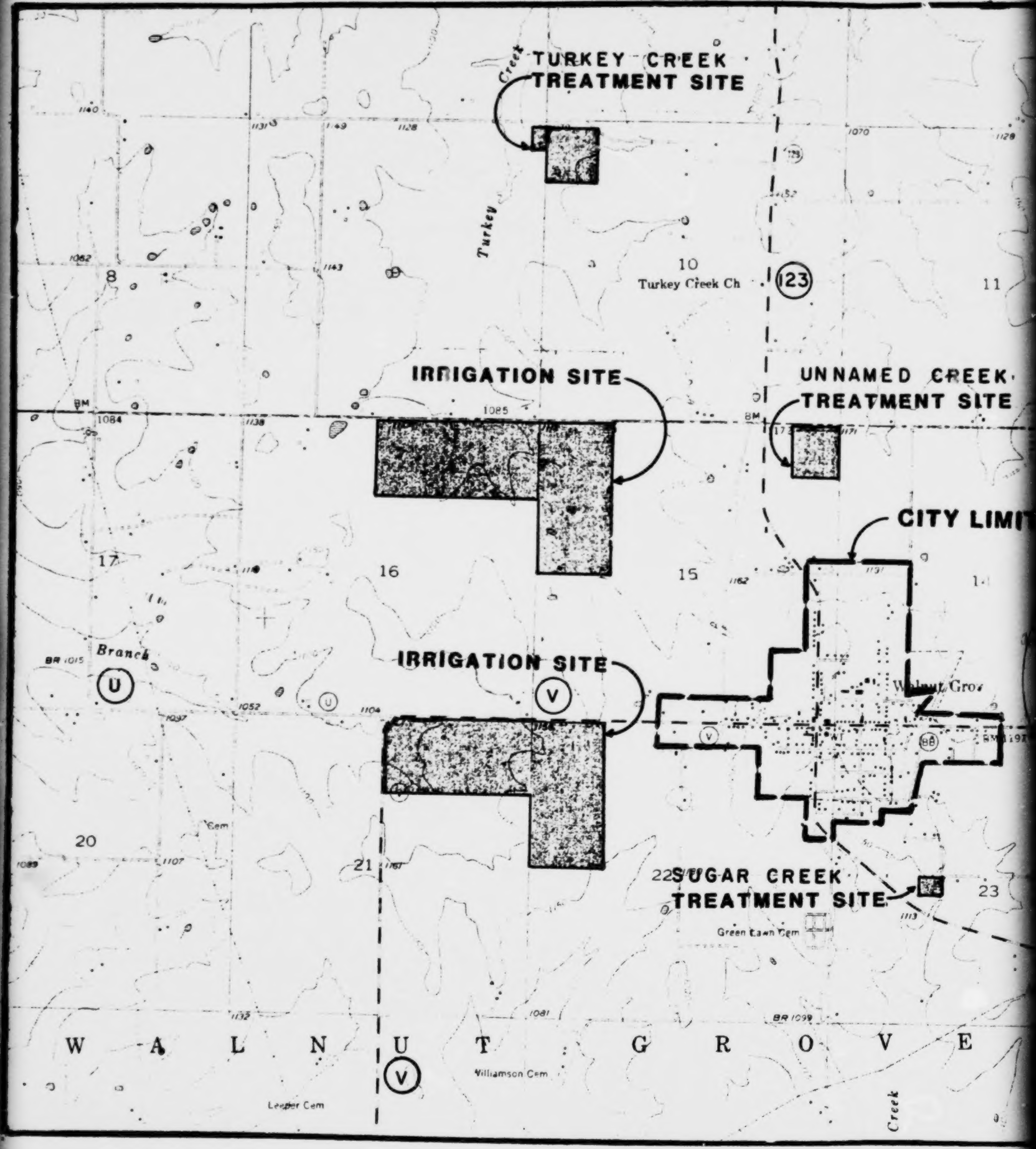
Alternatives evaluated for the subarea (see Figures 40, 46 and 47) are 1) no action (or improvement of existing systems), 2) a treatment plant discharging to an unnamed creek, 3) a treatment plant discharging to Sugar Creek, 4) a treatment plant discharging to Turkey Creek, 5) a pump station and force main to Ash Grove, and 6) land application. For central collection and treatment systems, gravity, pressure, and combination collection and on-site system alternatives are included. Total project, annual O&M, and total annual cost estimates of the alternatives are presented in Table 39.

1. No Action

Without federal and state funding assistance, it is unlikely that any central collection and treatment system could be financed. No action alternatives mean continued use of existing septic tank systems and installation of new ones. The City of Walnut Grove and Greene County may control and manage on-site systems to varying degrees. Soil and geological conditions preclude the longer term acceptability of on-site systems in many areas.

2. Unnamed Creek Treatment Plant

The creek is tentatively a gaining stream, but is being reevaluated. If gaining stream effluent requirements apply (refer to


TURKEY CREEK TREATMENT SITE
IRRIGATION SITE
UNNAMED CREEK TREATMENT SITE
CITY LIMIT
IRRIGATION SITE
SUGAR CREEK TREATMENT SITE
Turkey Creek
Turkey Creek Ch
123
10
11
8
17
16
15
14
20
21
22
23
BM
1085
1084
1140
1131
1149
1128
1082
1143
1138
1070
1129
1162
1131
BR 1015
Branch
U
V
1052
1104
1097
1107
1089
1161
88
Walnut Grov
Cem
Green Lawn Cem
1113
1132
1081
BR 1099
W A L N U T G R O V E
Williamson Cem
Leeper Cem
Creek

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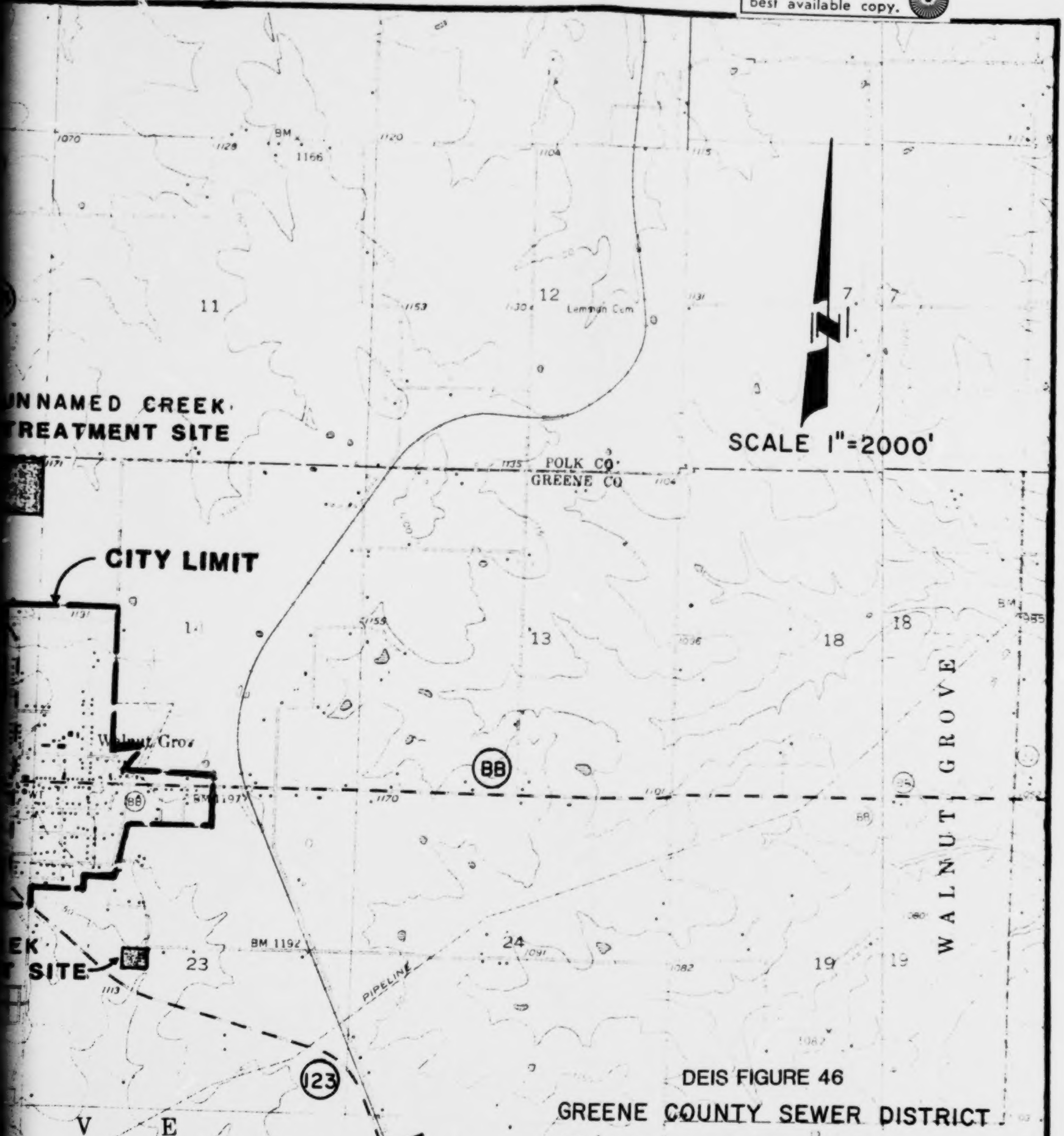

DEIS FIGURE 46

GREENE COUNTY SEWER DISTRICT
WALNUT GROVE, MISSOURI SUBAREA
PLANNING AREA & TREATMENT SITES
FIGURE 1

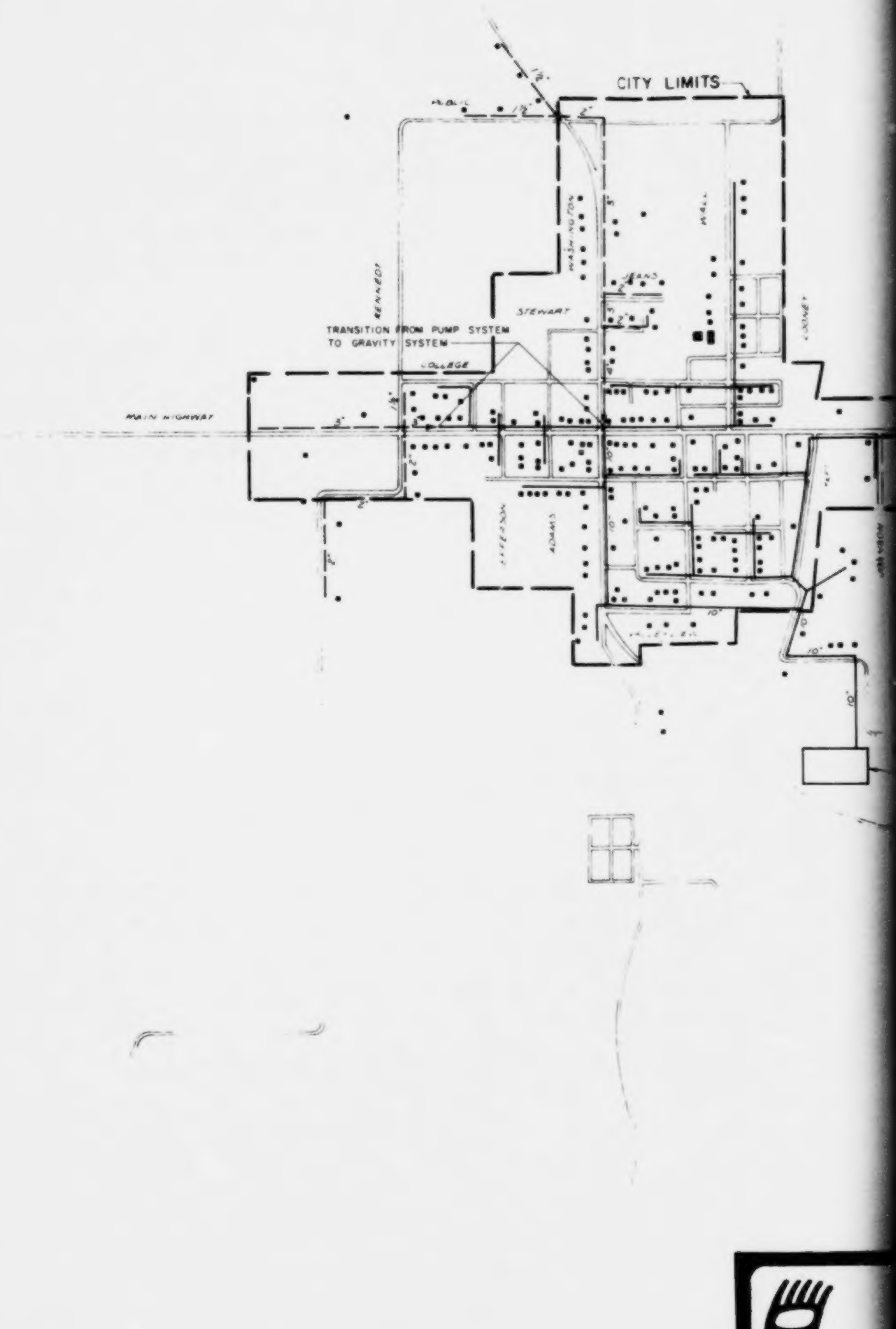

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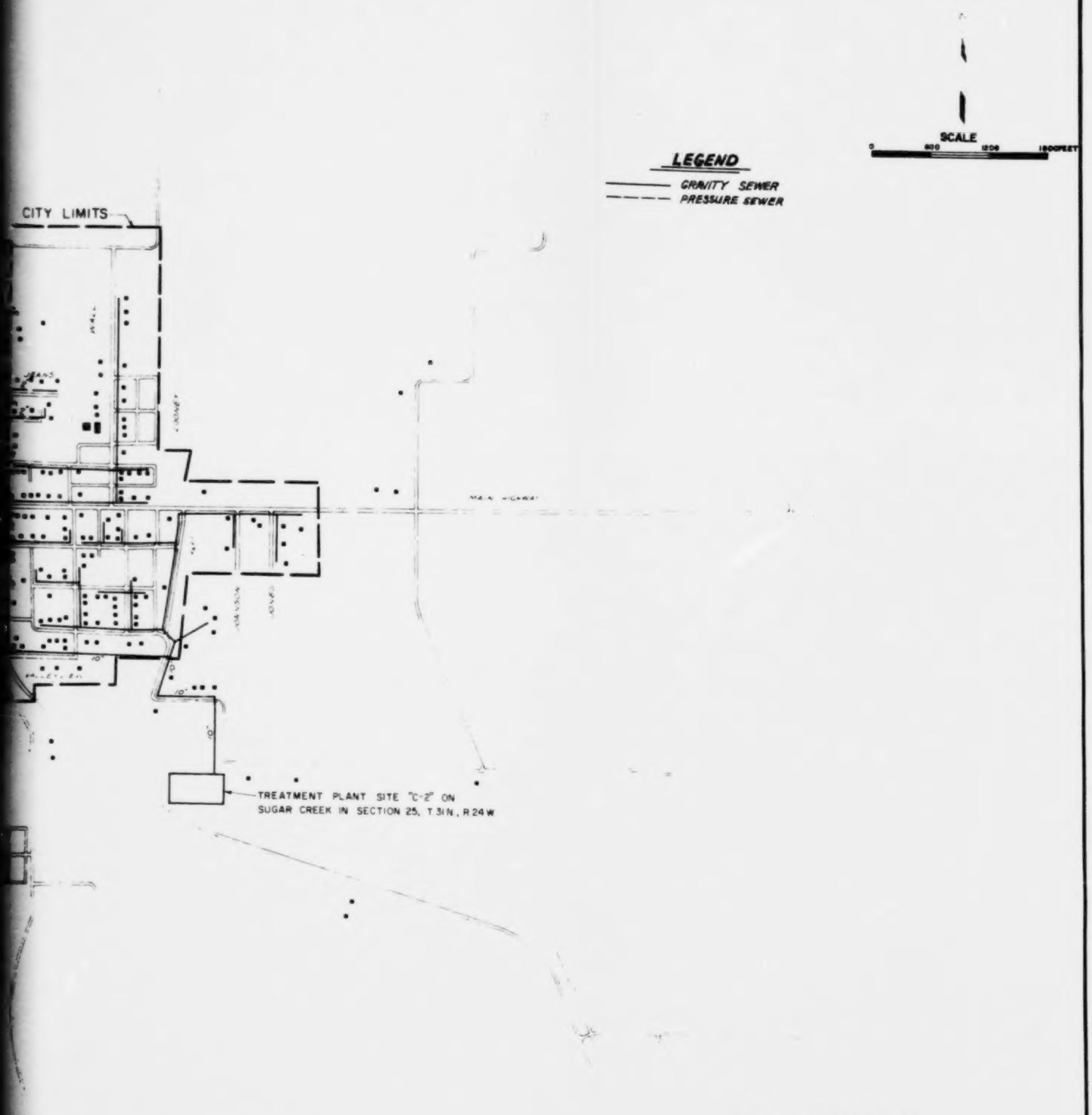
FIGURE 5



DEIS FIGURE 47

SUGAR CREEK ALT. C-2

McCALEB
ASSOCIATES, INC.
ARCHITECTS & ENGINEERS
P.O. BOX 111 405/341-1114
EDMOND, OKLA. 73034

HR

COMBINATION SYSTEM
WALNUT GROVE, MISSOURI

HOOD-RICH
ARCHITECTS & CONSULTING ENGINEERS
801 SOUTH GLENSTONE
SPRINGFIELD, MISSOURI 65802

SHEET 7 OF 8

DATE 11-24-82

TABLE 39
WALNUT GROVE SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Unnamed Creek Treatment Plant			
Gravity	$1,957,660	$31,945	$205,173
Pressure/Grinder Pumps	1,825,420	39,980	220,580
Pressure/Effluent Pumps	1,744,925	44,420	215,820
Combination/Gravity, Grinder, On-site	1,826,285	37,010	208,543
Combination/Gravity, Effluent, On-site	1,790,374	39,210	206,627
Sugar Creek Treatment Plant(a)			
Gravity	1,736,412	31,855	186,438
Pressure/Grinder Pumps	1,710,291	39,890	210,799
Pressure/Effluent Pumps	1,629,771	44,330	206,037
Combination/Gravity, Grinder	1,511,157	32,685	171,119
Combination/Gravity, Effluent	1,495,352	33,545	170,088
Turkey Creek Treatment Plant	Costs would be higher because of losing stream effluent requirements		
Pump Station to Ash Grove			
Gravity	2,126,426	33,610(b)	217,521
Pressure/Grinder Pumps	2,100,630	41,645(b)	241,915
Pressure/Effluent Pumps	2,020,164	46,085(b)	237,158
Combination/Gravity, Grinder	1,901,644	34,440(b)	202,160
Combination/Gravity, Effluent	1,886,167	35,300(b)	201,250
Land Application			
Combination	2,079,000	51,615	250,943

(a) Based on gaining stream effluent requirements.
(b) Includes estimated treatment costs.

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Table 6), the treatment system for meeting effluent requirements would consist of an oxidation ditch and two clarifiers. Effluent quality of 15 mg/l BOD and 15 mg/l SS can be expected.

3. Sugar Creek Treatment Plant (Proposed in Draft Facilities Plan)

Sugar Creek was thought to be a gaining stream at the time the Draft Facilities Plan was prepared, but subsequent investigations have shown the lower reaches of Sugar Creek to be losing and losing stream effluent requirements apply (refer to Table 6).

The Draft Facilities Plan treatment system for meeting gaining stream effluent requirements would consist of an aerated lagoon followed by a polishing cell and chlorine disinfection. This system with an estimated total capital cost of $1,489,400 and annual O&M cost of $33,545 is being reevaluated in light of losing stream requirements.

4. Turkey Creek Treatment Plant

Turkey Creek is gaining upstream of the plant site, but loses all flow to a bedrock fissure near the site. The stream is thus a losing stream, and losing stream effluent requirements apply (refer to Table 6).

The treatment system for meeting effluent requirements would consist of an oxidation ditch, two clarifiers, gravity sand filtration, and chlorine disinfection. Effluent quality of 2 to 10 mg/l BOD and 1 to 10 mg/l SS can be expected. Since costs for this system would be significantly higher, this alternative was dropped from further consideration.

5. Pump Station to Ash Grove

A pump station and about 36,000 feet of 6" force main would be installed to deliver raw wastewater to the Ash Grove system. An aerated flow equalization basin and chlorination facilities to help prevent septic conditions would be provided.

6. Land Application

A 0.14 acre aerated lagoon and center pivot spray irrigation system would be provided. A 3.44 acre sealed storage basin with 5½ months capacity would hold the lagoon effluent during the winter. Monitoring wells and fencing are provided. At a low application rate of

15 inches per year because of soil limitations, 60 acres are required for the application site. Costs include land purchase for the lagoon and storage basin, but application would be on private land. Land application is not cost-effective because of the soils limitations, storage requirements, and related high costs.

H. WILLARD SUBAREA

The Willard subarea is presently served by individual wastewater disposal systems. Planning for the subarea is based on 1980 and projected design year population as follows:

	Population Equivalent			
	1980		2005	
Willard Residents	1,799		4,306	
Willard Businesses	-		430	
Unincorporated Residents	241		317	
Non-Resident Students	403	(1610)*	491	(1,964)*
Total	2,443		5,544	

* Number of Students

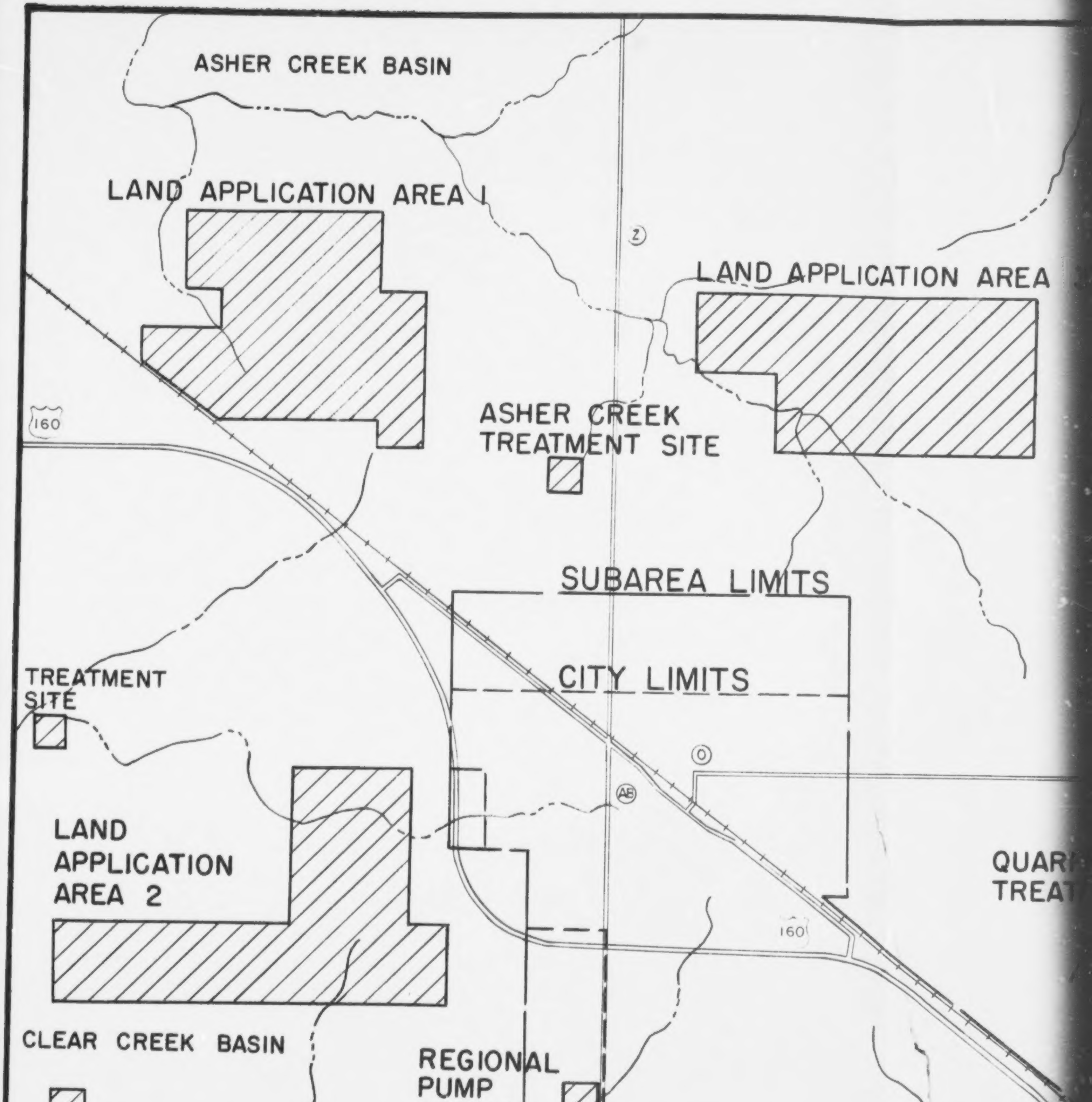
The design population equivalent is thus about 5540, and the average dry weather design flow at 75 gpcd is 0.416 MGD. Existing water use is about 60 gpcd, but 75 gpcd was used to allow for increased usage if on-site wastewater disposal constraints are removed.

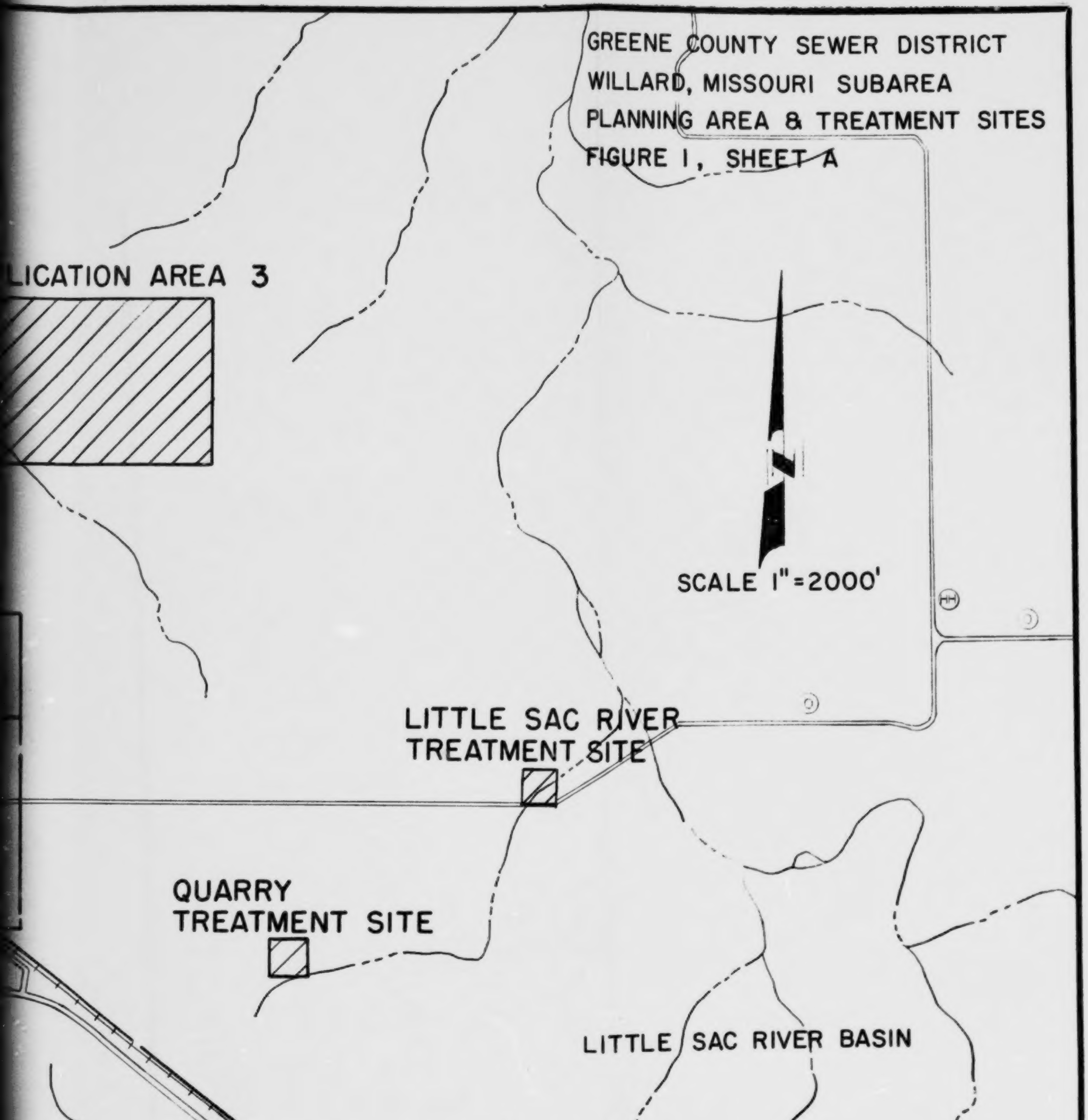
Alternative plans for the subarea are (see Figures 48A, 48B, and 49) 1) no action (or improvement of existing systems), 2) a treatment plant discharging to Asher Creek, 3) a treatment plant discharging to the Little Sac River, 4) a treatment plant discharging to a Little Sac River tributary branch, 5) a regional pump station to the Springfield system, and 6) land application. For the central collection and treatment systems, gravity, pressure, vacuum, and combination collection and on-site system alternatives are included. Alternatives for treatment and discharge to Clear Creek were dropped earlier in the facilities planning process because of public objection.

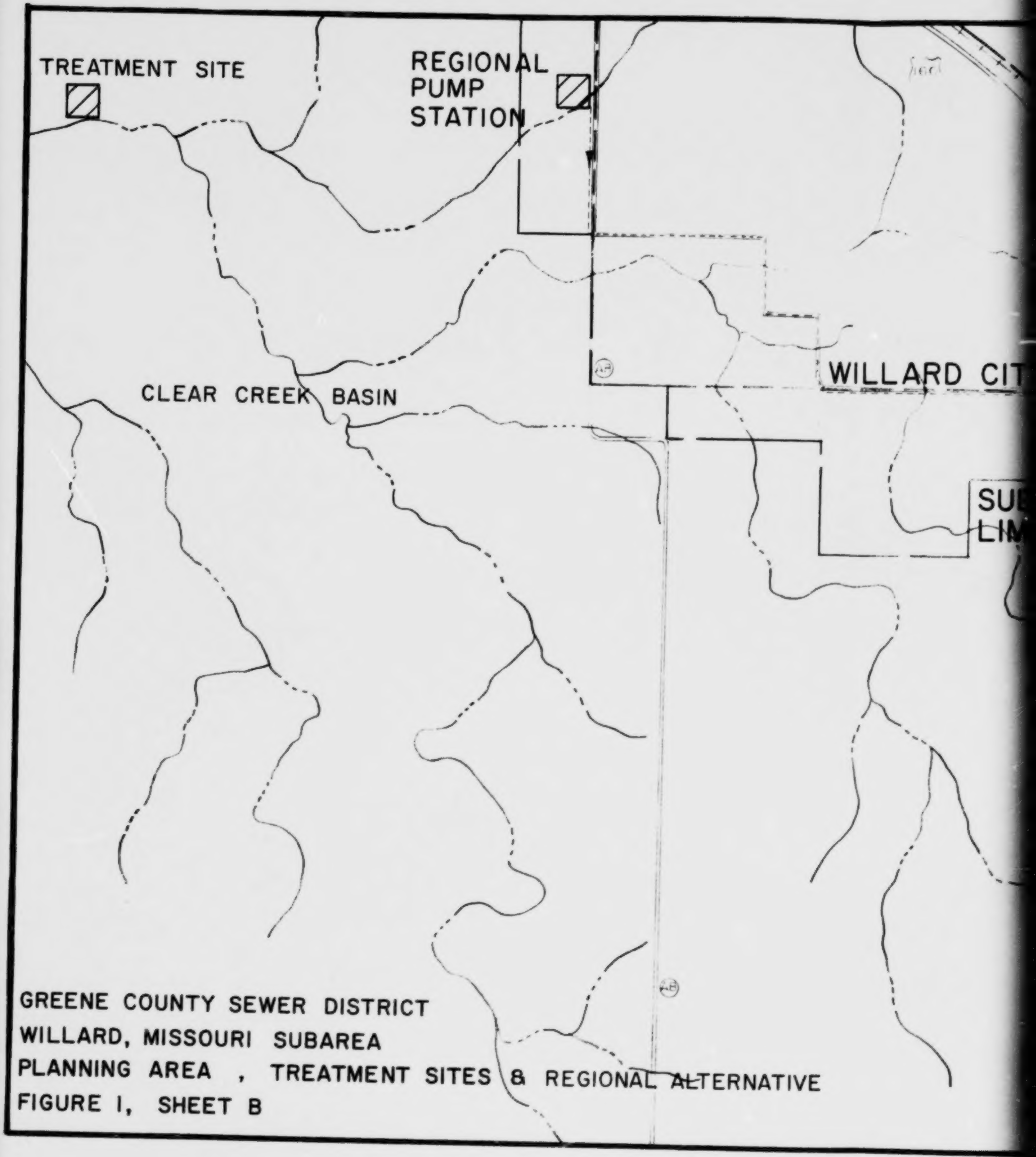
Total project, annual O&M, and total annual costs for each alternative are presented in Table 40.

TABLE 40
WILLARD SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY

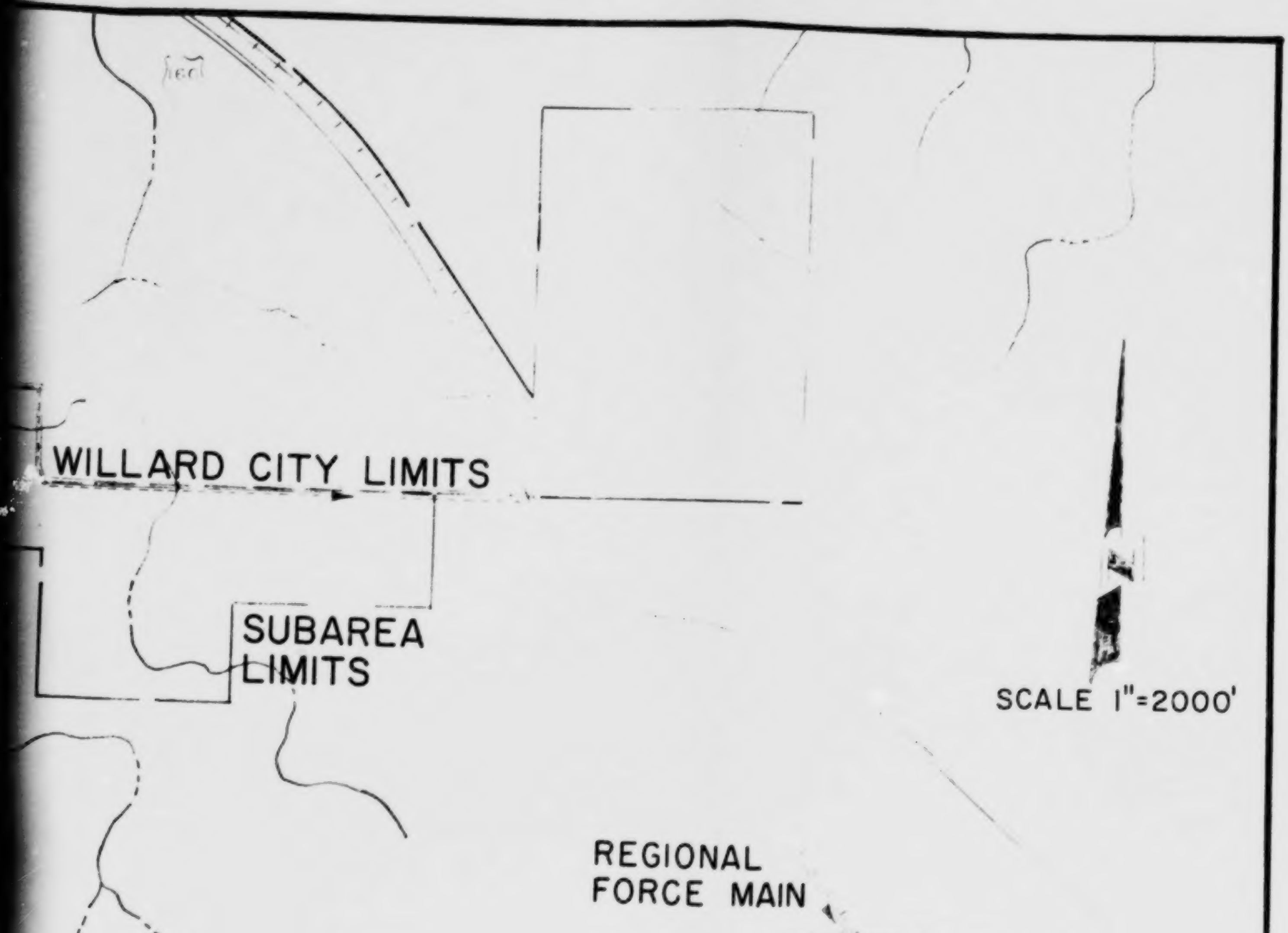
	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Asher Creek Plant			
Gravity	$6,006,900	$ 53,835	$600,100
Pressure/Grinder Pumps	6,035,800	85,010	781,925
Pressure/Effluent Pumps	5,687,400	95,010	737,560
Vacuum	6,318,500	104,465	764,660
Combination/Gravity, Grinder	5,603,300	58,090	582,455
Combination/Gravity, Effluent	5,588,700	58,795	580,120
Combination/Gravity, Grinder, On-site	5,292,500	58,250	577,425
Combination/Gravity, Effluent, On-site	5,248,300	59,295	572,120
Little Sac River Plant			
Gravity	6,306,600	53,710	625,265
Pressure/Grinder Pumps	6,076,000	83,140	783,225
Pressure/Effluent Pumps	5,723,700	93,120	738,460
Vacuum	6,439,000	102,595	773,000
Combination/Gravity, Grinder	5,919,300	57,865	608,700
Combination/Gravity, Effluent	5,903,700	58,530	606,290
Combination/Gravity, Grinder, On-site	5,569,800	58,430	600,910
Combination/Gravity, Effluent, On-site	5,527,200	59,430	595,720
Regional Pump Station to Springfield			
Gravity	5,314,300	76,100 to 119,980*	556,100 to 599,980
Pressure/Grinder Pumps	5,587,500	109,185 to 146,145*	760,700 to 797,660
Pressure/Effluent Pumps	5,235,200	119,185 to 156,145*	715,850 to 752,810
Vacuum	5,540,500	120,325 to 157,285*	705,300 to 742,260


ASHER CREEK BASIN
LAND APPLICATION AREA 1
Z
LAND APPLICATION AREA
160
ASHER CREEK
TREATMENT SITE
SUBAREA LIMITS
CITY LIMITS
TREATMENT
SITE
O
AB
LAND
APPLICATION
AREA 2
QUAR
TREAT
160
CLEAR CREEK BASIN
REGIONAL
PUMP
STATION
TREATMENT
SITE


GREENE COUNTY SEWER DISTRICT
WILLARD, MISSOURI SUBAREA
PLANNING AREA & TREATMENT SITES
FIGURE 1, SHEET A
LICATION AREA 3
SCALE 1" = 2000'
LITTLE SAC RIVER TREATMENT SITE
QUARRY TREATMENT SITE
LITTLE SAC RIVER BASIN
DEIS FIGURE 48A



GREENE COUNTY SEWER DISTRICT
WILLARD, MISSOURI SUBAREA
PLANNING AREA , TREATMENT SITES & REGIONAL ALTERNATIVE
FIGURE 1, SHEET B



DEIS FIGURE 48B

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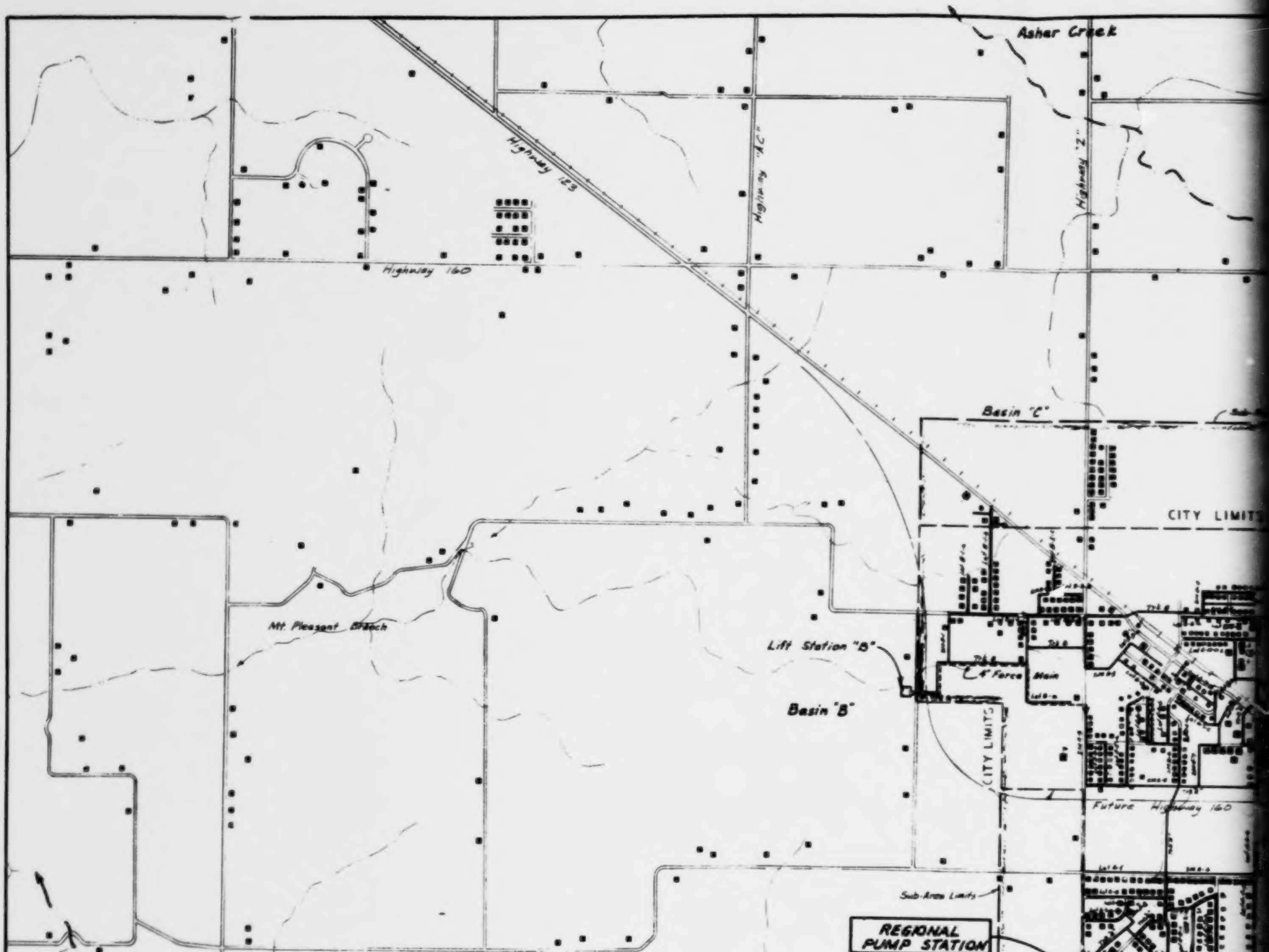

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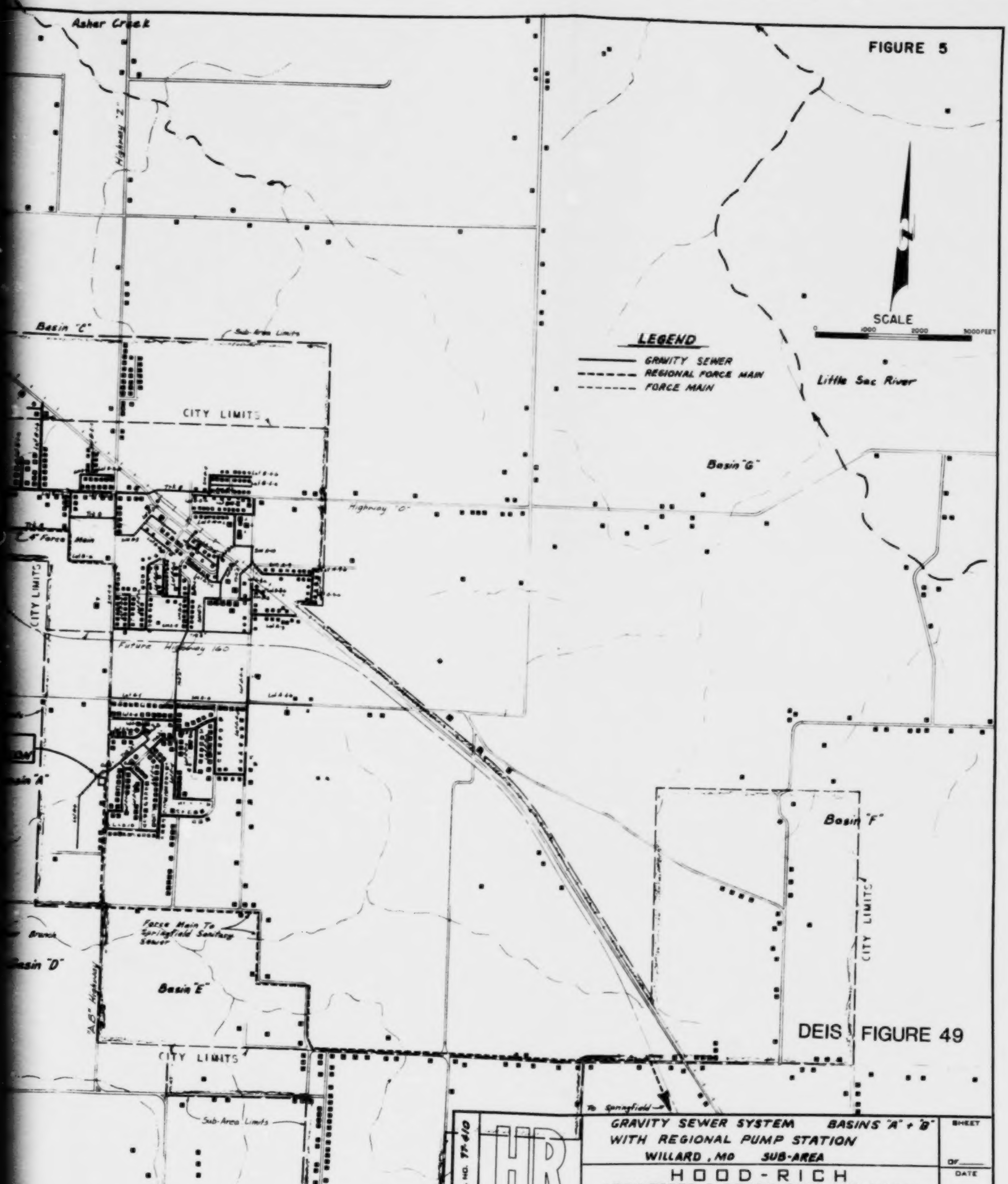
FIGURE 5



DEIS FIGURE 49

TABLE 40
WILLARD SUBAREA
ALTERNATIVES PRELIMINARY COSTS SUMMARY (continued)

	Total Project Cost	Annual O&M Cost	Total Annual Equivalent Cost
Regional Pump Station to Springfield			
Combination/Gravity, Grinder	$4,911,200	$ 79,525 to 116,485*	$537,745 to 574,705
Combination/Gravity, Effluent	4,896,700	80,230 to 117,190*	535,420 to 572,380
Combination/Gravity, Grinder, On-site	4,599,600	79,685 to 116,645*	532,570 569,530
Combination/Gravity, Effluent, On-site	4,555,200	80,730 to 117,690*	527,250 to 564,210
Land Application			
Gravity	6,501,500	125,960	723,895
Pressure/Grinder Pumps	6,530,500	157,535	906,130
Pressure/Effluent Pumps	6,183,100	167,535	861,765
Vacuum	6,813,000	176,990	888,845
Combination/Gravity, Grinder	6,097,900	130,615	706,650
Combination/Gravity, Effluent	6,083,300	131,320	704,310
Combination/Gravity, Grinder, On-site	5,786,700	130,775	701,580
Combination/Gravity, Effluent, On-site	5,743,400	131,820	696,370

* Depending on treatment costs.

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1. No Action

Without federal and state funding assistance, it is unlikely that any central collection and treatment system could be financed. No action alternatives mean continued use of existing septic tank and small treatment systems and installation of new ones. The City of Willard and Greene County may control and manage on-site systems to varying degrees. Soil and geological conditions preclude the longer term acceptability of on-site systems in many areas.

2. Asher Creek Treatment Plant

Asher Creek is a losing stream, and losing stream effluent requirements apply (refer to Table 6). The treatment system for meeting effluent requirements would consist of an oxidation ditch, two clarifiers, gravity sand filtration, and chlorine disinfection. Sludge holding facilities and drying beds would be provided. Anticipated effluent quality is 2 to 10 mg/l BOD and 1 to 10 mg/l SS.

3. Little Sac River Plant

The Little Sac River is effluent-limited with the following requirements for the Northwest Treatment Plant based on a draft updated waste load allocation study (66):

BOD (mg/l)	20
SS (mg/l)	20
pH	6.0 to 9.0
Ammonia (mg/l)	2.0
Dissolved oxygen (mg/l)	6.0 (or 80% saturation, whichever is less)

The treatment system for a plant serving Willard and meeting similar requirements would consist of an oxidation ditch, two clarifiers, and gravity sand filtration. Effluent quality of 2 to 10 mg/l BOD, 1 to 10 mg/l SS, and 2 mg/l ammonia can be expected. The draft updated waste load allocation study concludes, however, that a secondary treatment plant for Willard will be adequate for discharge to the Little Sac River (66).

4. Little Sac River Tributary Plant

A site on a small tributary branch of the Little Sac River was considered. Geological investigation showed this to be a losing stream, and losing stream effluent requirements would apply. Treatment would be the same as for the Asher Creek plant.

5. Regional Pump Station to Springfield (Proposed in Draft Facilities Plan)

A pump station and about 33,000 ft of force main would be provided to deliver raw wastewater to the Springfield Airport Branch Trunk and Northwest Treatment Plant. A 24-hour holding basin would be provided at the pump station to handle peak flows and provide storage in case of failure. Chlorination at the pump station would be provided to help prevent the wastewater from becoming septic.

The total capital cost of the proposed project is $3,153,600. The project would provide a gravity collection system only for sub-basins "A and B" of the Willard subarea. Other areas would continue to be served by on-site systems. Depending upon an appropriate inter-governmental agreement, operation and maintenance, as well as treatment, would be the responsibility of the City of Springfield, and Springfield's normal sewer service charges would be billed to Willard customers.

6. Land Application

A 1.0 acre aerated lagoon and center pivot spray irrigation system would be provided. A 23.4 acre sealed storage basin with 5½ months capacity would hold the lagoon effluent during the winter. Monitoring wells and fencing are provided. At a low application rate of 18 inches per year because of soil limitations, 345 acres are required for the application site. Costs include land purchase for the lagoon and storage basin, but application would be on private land. Land application is not cost-effective because of the soils limitations, storage requirements, and related high costs.

I. UNINCORPORATED LOW GROWTH SUBAREA

The unincorporated low growth subarea is served almost entirely by septic tank wastewater disposal systems. Planning for the subarea is based on 1980 and projected population as follows:

Population			
	1980	2005	2025
Residents	13,461	16,169	17,562

At 2.8 persons per household, there would be about 4808 homes in the subarea of which 409 are in platted subdivisions and the remainder scattered throughout. At an estimated 85 gpcd, the year 2005 wastewater flow would be 1.374 MGD. This water use is based upon a few homes served by public water systems although most depend upon individual wells. There are no industrial or institutional facilities in this subarea and future wastewater flows are also expected to be only domestic wastes from residences and small commercial establishments.

Wastewater disposal alternatives for the low growth subarea are improvement of existing individual systems, and construction of small central collection and treatment systems or cluster systems for subdivisions and other more densely developed areas. The methods and criteria discussed in this section may also be applied as at least interim solutions for other unsewered subareas (or unsewered portions of other subareas), pending installation of sewers.

The conventional septic tank and absorption field is widely used for on-site treatment. Variations and alternatives to this system include:

- septic tank and dosed or pressurized absorption field distribution
- aerated tank and absorption field
- aerated tank and sand filter
- mound system
- lagoon
- septic tank and recirculating rock filter
- activated sludge treatment plant
- land application

The last four systems usually have a surface discharge of effluent while the others are designed for subsurface liquid disposal.

Methods to modify wastewater characteristics through reduction of flow or pollutant mass should be considered. Good practice requires that water conservation/flow reduction be employed at a dwelling served by an on-site wastewater system.

1. Improvements of Subsurface Disposal Systems

Common types of failures of septic tank and absorption field systems are wet weather surfacing of effluent, long-term clogging of absorption fields, and ground water contamination. If the soil percolation rate is 120 minutes per inch or less (percolation test time greater than 120 minutes) flooding during periods of heavy rain is likely regardless of effluent loading per sq ft of trench or trench spacing. Long-term plugging of the absorption field can be caused by: formation of a biological mat which clogs the soil voids, particularly, under anaerobic conditions; improper smearing or compaction of the soil face during construction; and overflow of solids from the septic tank. Groundwater contamination may occur in areas of shallow fractured bedrock, periodic high water table, saturated soils, and soils that percolate too rapidly or contain holes or other large openings. Surfacing effluent in fragipan soils may reenter the ground water through sinkholes or other interconnections.

Key factors in on-site subsurface disposal are unsaturated soil conditions, aerobic periods for absorption field recovery, proper construction practices, proper pre-treatment, and adequate operation and maintenance. The variations to conventional septic tank systems are attempts to remedy particular problems, but are not without cost and other possible performance disadvantages that must be weighed.

Continued use of on-site treatment systems with proper system design, construction, and operation is environmentally sound for many parts of the unincorporated low growth subarea. Criteria developed in the Draft Facilities Plan are:

Criterion	Adsorption Fields	Mound Systems	Land Application
Depth to rock or restrictive layer (ft)	5	2	2
Depth to water table (ft)	5	2	2
Percolation rate (min/in)	10 to 100	0 to 100	10 to 100
Surface flooding	Rare, Brief	Occasional, Brief	None
Maximum Slope (%)	15	15	15

These criteria will require site evaluation in addition to the common percolation test. Additional design parameters for subsurface disposal systems are:

Adsorption Systems

Loading rate (gpd/sq ft)	Varies from 0.2 to 0.65 depending on percolation rate from 90 to 10 min/in, respectively
Trench width (ft)	2
Maximum trench length (ft)	100
Trench spacing (ft)	10 center to center
Maximum trench depth (ft)	2
Trench grade	Flat
Application method	Dose twice per day for slopes less than 5%; gravity for slopes greater than 5%
Construction Period	Dry soil required

Mound Systems

Maximum top loading rate (gpd/sq ft)	1.2
Maximum base loading rate (gpd/sq ft)	Varies from 0.2 to 0.7 depending on percolation rate from 90 to 0 min/in, respectively

Maximum side slope	3 : 1
Height above natural ground (ft)	3
Fill material	Sand
Cover material	6 to 12 inches of topsoil, seeded
Application method	Dosed 4 times per day
Construction period	Dry soil required

Land Application Systems

Loading rate (in/day)	Varies from 0.5 to 1.6 depending on percolation rate from 90 to 10 min/in, respectively.
Application method	Spray
Application period	160 days per year

Pre-Treatment Systems

Capacity	1.5 times flow, 500 gal. min.
Flow control	Sanitary tees or baffles at inlet and outlet with air gap above
Gas deflection	Gas deflection baffle under outlet
Access	Access ports at inlet and outlet, one extended to ground level

Storage Basin for Land Application

Storage capacity (days)	200
Storage depth (ft)	3 to 5
Sealing	Excavate and rework 12 inch bottom layer for 1/16 inch per day maximum loss
Safety	Fence around basin

2. Improvement of Surface Disposal Systems

Surface disposal systems treat the wastewater to an acceptable level, then discharge it to a surface waterway such as a ditch or stream, not depending upon soils for final treatment. The systems will vary depending upon effluent requirements and cost and design processes, considerations similar to those for municipal systems as previously described. Inadequate operation and maintenance of such small systems is a widespread problem and failures may occur from periodic upsets of the treatment process, system overloading, and systems that do not meet current regulations. Small mechanical treatment plants are often prone to process upsets because of operating deficiencies and wasteload fluctuations. Lagoon systems may not produce satisfactorily effluent or may leak excessive or poorly treated flow to the subsurface. In recent years, effluent requirements for lagoons were relaxed because of their inability to meet the standard definition of secondary treatment. "No-discharge" lagoons may discharge periodically during wet periods as well as leak wastewater to the subsurface.

3. Modification of Wastewater Characteristics

Wastewater modification methods encompass three basic interrelated strategies: water conservation and wastewater flow reduction, pollutant mass reduction, and on-site containment for off-site disposal. Each strategy attempts to reduce the influent wastewater loading to the on-site disposal system (232).

Flow reduction methods include the elimination of wasted water; water-saving devices, fixtures, and applicances; and water recycle systems. Improved maintenance of plumbing and appliances and nonexcessive water supply pressure are means of reducing water waste. Low-volume flush toilets, non-water carriage toilets, reduced-flow showerheads, adjustable cycle settings or recycle systems on clothes washing appliances, pressure-reducing valves, and hot water pipe insulation are examples of water-saving devices, fixtures and appliances. Over 70% of typical residential wastewater flow is generated by toilet flushing, bathing, and clothes washing and efforts towards flow reduction should be so directed.

Wastewater recycle systems collect and process all wastewater or the portion produced by certain activities for subsequent reuse. To simplify the performance requirements, most recycle systems process only the wastewaters from bathing, laundry, and bathroom sink usage, and restrict the use of recycled water to flushing toilets and possibly lawn irrigation. Wastewaters generated by fixtures other than toilets are often referred to collectively as "graywater." Graywater does contain appreciable quantities of pollutants and treatment methods are similar to those employed for total household wastewater.

The costs of various types of waterless and low flow toilets were estimated in comparison to conventional 5-gallon tank units. The costs are based upon two installed units over a 20-year period, and include capital and operating costs less the estimated savings from a smaller septic system absorption field (based upon 36 percent less flow for a waterless toilet household). The estimated costs were: a range of $2,540 to $4,150 for various waterless composting toilets; $1,750 for a 2-quart air and water flush type; $290 for a 3-gallon tank model; and $590 for the conventional 5-gallon tank type.

Pollutant loadings to on-site systems can be reduced by such measures as disposing of diapers and garbage with solid waste rather than adding to the wastewater stream. The use of low phosphorus detergents and cleaning agents will substantially reduce phosphorus in household wastewater. On-site containment of wastewater in holding tanks for subsequent transport and disposal is another alternative.

Some of the methods discussed above would require extensive modifications to plumbing systems and would probably not conform with existing local plumbing codes. The Citizens Advisory Council to the Greene County Facilities Plan rejected composting and 2-quart flush toilets as expensive, impracticable, and unacceptable.

4. On-Site System Management

Adoption of an on-site system management plan is a controversial issue (but necessary for effective and proper on-site system use in areas such as these) and requires many detailed items to be effective. The goals of the plan would be:

- Sound design and construction practices.

- Periodic inspection to detect problems.
- Periodic removal of septic tank solids with proper disposal.
- Periodic maintenance of pumps, dosing siphons, and other equipment.
- Wastewater characteristics modification, particularly flow reduction.

IV. GENERAL IMPACT ASSESSMENT

This section discusses, in general, both the beneficial and adverse impacts that can be expected from the construction and operation of the various wastewater collection and treatment alternatives considered for the planning area. The discussion not only describes the impacts that can occur, but also provides information on the causes of impacts, possible secondary effects, and mitigative measures. The impacts are described here on a non-site-specific basis. In the next section, the impacts are evaluated in terms of the specific facilities plan alternatives presented in Section III.

A. GEOLOGY & SOILS

The geology and soils of the planning area present certain problems and constraints to alternatives for sewage treatment. Problems include permeable and jointed bedrock at or near the ground surface; losing reaches of streams in the area; sinkholes, springs, aquifers, and caves forming an interconnected subsurface network; soils with a dense layer of low permeability known as a fragipan; areas with sinkholes and potential subsidence; highly irregular bedrock surfaces with pinnacles; soils with high shrink-swell characteristics; an upper aquifer with openings to the surface and a lower aquifer under artesian pressure; and a climate that causes frozen ground and wet periods.

Excavation and grading for wastewater treatment facilities will alter the surface topography, geology, and soils within the construction zones. The alternatives recommended in the Facilities Plan involve constructing new sewer lines, pump stations, and treatment plants and expanding existing facilities. Effects upon on-site septic systems performance are also important as discussed in Section II-A.

1. Topography and Geology

Constructing sewer lines will temporarily disturb small areas at a time, and is generally considered a minor impact. Blasting and rock drilling may be required where sewer lines are routed across rocky areas, such as the upper reaches of drainage areas, but would result in only minor disturbance of local topography. Only minor topographic impacts are indicated from sewer line construction since all buried lines would be backfilled with excavated material to the original ground level. Treatment plant, lagoon, package plant, and lift station areas would be graded and thus slightly alter the topography, but because the areas involved are small and many are in undeveloped locations, the impact is considered to be slight. Construction of interceptors in the project area would not adversely affect the topographic setting.

Impacts result from the bedrock that occurs near or at the surface. Installing collection systems in these areas may require bedrock excavation and blasting during construction. The blasting would be of limited duration in each segment which reduces the magnitude of the impact, but construction costs are substantially higher.

Construction in bedrock will cause minor alterations of geological features. Sewer lines and foundations placed in rock will require its removal and off-site disposal. Sewer lines constructed in rock create possible avenues of contamination. There will be no significant loss of commercial value of rock or mineral resources.

Construction of sewage collection and treatment facilities in areas of sinkholes is not recommended because of the potential for collapse and subsidence. Sinkholes provide direct connection to subsurface drainage passages and the shallow aquifer in the planning area.

2. Soils

The origin of soils in the planning area include loess (silt), silty and clayey alluvials and residuals from weathering of shale, cherty limestone and dolomite, sandstone, and siltstone. Soils will be affected by the proposed actions. The soils are subject to erosion resulting in dust, sedimentation, and turbidity during any construction period until vegetation has again been established. Existing soil structure and other soil properties would be altered by construction of treatment plants, pump stations, lagoons, and sewer lines. Some of the physical, chemical, and biological systems associated with the natural soil building process would be disrupted and changed. Construction will have a short-term impact of lowering the soil's inherent natural productivity.

Some soils have a fragipan, a dense layer of low permeability. Excavation penetrating these layers allows vertical drainage to enter the soils and rock below. Construction on these soils that does not penetrate the fragipan layer can cause drainage to travel across the ground surface after a rain and enter a poorly constructed well or other natural feature connected to subsurface drainage.

Excavation for sewers results in soil intermixing. In some cases, soils unsuitable for plant growth are brought to the surface. Excavated soil would be placed in temporary spoil banks along the pipeline route until the line is installed. Because many sewer lines will be located along creeks and roadways, this intermixing is considered a minor impacts.

Certain soils within the planning area have been classified as "Prime Farmland Soils" by the USDA Soil Conservation Service. Sewer lines in the upper reaches of creeks would involve prime farmland. The interceptor systems would impact the prime farmland, but because the construction in any one area would be restricted to a relatively narrow right-of-way and limited to a single growing season, the impact is considered slight and short-term. Once the sewer line is in place, the agricultural productivity of the soil can be restored. The permanent easements passing through agricultural land would not preclude continued farming. Variables such as specific route location, the time of year in which construction occurs, the revegetation program, and maintenance procedures will ultimately determine the degree to which these short-term impacts affect the area's long-term productivity.

The sewage lift stations would have a minor impact on prime farmland. Construction will require disturbance and removal of soil for these installations. About 0.2 acres would be required for each lift station facility and this amount of prime farmland would be removed from agricultural use for as long as the facility remains in place.

Wastewater treatment plant construction would deny the area to other use during the life of the facility. Where this occurs in areas designated as "prime farmland", the area would be removed from agricultural production and is considered a long-term impact. Of the total agricultural acreage, this amount would be considered insignificant and the impact is therefore slight.

Prior to establishing vegetative cover on construction areas, ground-clearing operations will provide conditions suitable for soil erosion by wind and water. Effects of erosion would be temporary. After construction is completed, the ground surface will be returned to a condition comparable to its present state. Therefore, the impact is considered to be short-term.

Construction of the recommended alternatives would remove a number of acres from other productive uses for the life of the systems.

3. Mitigative Measures

Mitigative measures for impacts on topography include a grading plan that causes minimum disturbance to surface contours. The plan should also provide for proper drainage, slope stability, and revegetation. Spoil piles within the construction area should be temporary. If they become permanent, they should be graded to drain and planted to blend with the site's topography.

Several mitigative measures can be applied to reduce the impacts to the soils and terrestrial environment. Removal and temporary stockpiling of top soil should be required, so that it can be distributed over disturbed areas upon completion of construction. No reasonable and economical mitigative measures exist to prevent disturbance to subsoil. The excavation and backfill operations mix and bury the subsoil in disorder, therefore, excavated areas should be kept to a minimum. Backfill compaction should be such that settlement and subsidence are prevented. The exposure period of raw soils should be minimized to decrease erosion, the accompanying turbidity and siltation of streams, and the generation of airborne dust. Steep slopes should be planted or otherwise protected against slope failures and erosion. Deep excavation in poor subsoil should require shoring to keep disturbance to a minimum and provide safe working conditions. Water should be sprayed on exposed soils to prevent dust, when this is a problem. Storm water retention basins to detain peak runoff and mimimize stream siltation and turbidity should be provided at construction sites. These measures will be particularly important for construction in areas which drain to sinkholes or to streams furnishing Springfield's drinking water supply such as the James River and McDaniel Lake.

Blasting requires emphasis on safety precautions. Excess rock not required for backfilling or other construction should be used for erosion protection, spoiled in such a manner as to blend with the surroundings, or hauled away for disposal at an approved site.

Mitigative measures for impacts on geology would include avoidance of construction across known sinkholes and losing portions of streams. If avoidance is not feasible, then provision should be made for sealing of the sinkholes and losing stream areas where construction comes in contact with these features.

Construction in and adjacent to streambeds should be mitigated by minimizing such construction and returning all stream crossings for sewer lines and heavy equipment to the approximate preconstruction conditions. Special care should be given to preserving the natural stream-side vegetation, and to preventing erosion in the watersheds upstream from the water supply sources in the James River, Fellows Lake and McDaniel Lake. Strict specifications requiring sediment control measures during construction, such as the use of sediment traps or ditch blocks, will help prevent sediment from entering the river or lakes.

New on-site treatment systems should be properly sited, designed and installed, and failing systems should be improved or corrected. Regulation with proper enforcement is the primary means of achieving on-site system improvements. Measures to reduce flow and pollutant load to on-site systems should be adopted. Connection to a central wastewater collection and treatment system should be implemented if possible. Mound systems may perform satisfactorily in areas of fragipan soils or shallow bedrock.

B. WATER RESOURCES

1. Surface Water

Construction is not expected to result in either benefical or adverse short-term impacts on surface hydrologic conditions. No long-term adverse impacts on surface features such as channel scouring or flooding are expected. Treatment plants and lift stations located in the flood plains of streams may require levee protection or design and siting efforts to place them above the 100-year flood level.

Impacts to stream flow caused by pipeline construction would be temporary and of little consequence except where major creek crossings occur in the lower reaches of the watershed. Existing septic systems that are not operating properly and small treatment plants discharging to small tributary streams would have minor impacts on surface water flows.

Construction effects of the treatment plant alternatives include erosion and flood plain infringement.

2. Ground Water

The environmental setting describes the major (lower) and minor (upper) aquifers in the planning area. Although the formation separating the two aquifers acts as a confining layer there is evidence that the two aquifers are hydraulically connected. Therefore, any pollution of the upper aquifer can be expected to migrate downward into the major aquifer. Pollution of the minor aquifer can be caused by accidental or intentional spillage or neglect.

Sewer lines that cross shallow aquifers, and sewage lagoons within the recharge areas of the minor aquifer pose a threat to water quality, should leaks develop. Improperly designed septic tank systems can also contribute to water pollution. These impacts are concerned with potential effluent surfacing and leakage into the minor aquifer. Insufficient thickness of suitable soil below septic absorption fields, areas too small for absorption fields, improper operation, and soils with slow permeability and fragipans result in pollution of ground and surface water.

Treatment plants and package plants may discharge pollutants in several ways. Discharge may be directly to a stream; effluent or sludge may be applied to land; or sludge may be landfilled. Because of the various soil and geological problems in the planning area, any of these methods could introduce pollution into the ground water aquifers. In the case of discharge to a losing stream, all or a portion of the flow enters the permeable bedrock and interconnected openings. This would provide an entry into the minor aquifer for any pollution that may be present in the stream.

Land application and landfill could impact the environment. Accidental discharge or the application of excess sludge would provide the source of pollution. If the location of the discharge is such that it could enter the permeable limestone and chert beds in soil, a losing stream, sinkholes, caves, or springs, then there is a possibility that pollution of the minor aquifer could happen. Land application on fragipan soils would allow flow across the ground surface, particularly after a rain, to enter any of the above or a poorly constructed well.

The climate in the planning area is such that frozen ground and wet seasons occur annually. Therefore, land application could not be practiced during these periods and holding basins would be required with a capacity to hold discharge during these periods.

The following geological and man-made features would afford a means for pollution to enter the minor aquifer: a permeable limestone formation at or near the surface; a losing stream where part of the underground flow is lost to subsurface drainageways; sinkholes, springs, and caves with interconnected subsurface drainageways; a fault or interconnected joints; permeable cherty soils; improperly constructed wells; and fragipan soils that prevent septic systems from working properly and allow septic tank liquids to flow across the ground surface and enter a subsurface drainage path. Any natural or man-made feature that provides a connection between the surface and the aquifers makes pollution of the aquifer a possibility. This is also true between the upper and lower aquifers.

A "no-action" alternative would result in continued pollution of the surface waters and upper aquifer from failing sewage treatment facilities.

3. Mitigative Measures

Possible mitigative measures on water resources would be that floodplain development be avoided and measures be taken at stream crossings to minimize stream cross-section changes. Flood waters could then flow without an increase in flood elevations caused by a decrease in the cross-sectional area of the streams, and without an increase in scouring and subsequent loss of land.

Mitigative measures for impacts on both surface and ground water would include good design and construction practice to prevent accidential leaks. Sewer alignments should avoid areas where the chance of subsidence or other earth movement is high. Proper bedding is required to prevent differential movement and possible line breaks.

C. WATER QUALITY AND AQUATIC ECOLOGY

As previously discussed, the surface water and ground water resources of the study area are extensively interconnected. Therefore, the quality of each is partially interdependent. Since the aquatic biota is determined, in part, by water quality, the aquatic ecology of the study area is also dependent on the interrelated surface and ground water quality. General impacts on water quality and aquatic ecology may be grouped in several major categories: those associated with contaminants added by wastewater effluents, induced (secondary) growth, potential treatment and collection system failures, improved wastewater treatment capabilities, and construction-related activities. These impacts include both positive (beneficial) and negative (adverse) aspects.

1. Contaminants in Wastewater Effluent

The impacts to the quality of the study area's surface waters will be due to contaminants in the proposed wastewater treatment plants' (WWTPs) effluents. All of the proposed WWTPs will provide, at least, secondary treatment processes. The existing Southwest (Wilsons Creek) and the proposed Northwest (Little Sac River) WWTPs have some advanced wastewater treatment capabilities for converting ammonia-nitrogen to less-toxic nitrate-nitrogen. The effluent limitations applicable to WWTP alternatives for the various subareas were presented in Section III.

The discharge of relatively high-quality effluents would still increase the ambient concentrations of many water quality parameters, including total suspended and dissolved solids, ammonia, nitrates, phosphates, biochemical and chemical oxygen demand, and bacteriological parameters. In addition, ambient concentrations of dissolved oxygen would probably be decreased. The magnitude of these potential impacts would depend on such factors as the specific type and reliability of the treatment method, the type of effluent disinfection (if any), the size of the receiving stream (particularly the base flow), the configuration of the stream channel downstream from the outfall, and the biological community inhabiting the stream. Another potential impact from contaminants in WWTP effluents concerns trihalomethanes (THMs) in drinking water supplies as described in Section II.

Chemical contaminants may also pose drinking water problems. Heavy metals, pesticides, or other trace inorganics and organics may be of concern, particularly, in industrial wastes. Wastewater disinfection with chlorine can form chlorinated organics of potential health significance. Chlorine may combine with organic compounds in wastewater to form other compounds with toxic or carcinogenic properties harmful in a drinking water supply. These compounds are also harmful or toxic to aquatic organisms (both surface dwellers and troglobites*). Also, drinking water contaminated by nitrate-rich WWTP effluents may cause methemoglobinemia in newborn infants.

The impacts of treated wastewater effluent on ground water quality concern two basic topics: the potential hazard or added treatment cost of using contaminated ground water as a drinking water supply, and endangering the survival of rare aquatic animals adapted for underground existence. Many of the streams in the study area contain reaches that are classified by MDNR as "losing streams." These reaches contribute surface water directly to the ground water. Any contaminants in WWTP effluents discharged to these streams may be transmitted directly to raw water supplies. Since most of the water supplies in the study area are from wells with little or no subsequent treatment (see Section II-I), the most severe potential hazard is bacterial contamination of public or private water supplies. Bacterial and chemical contamination of ground water has occurred in some portions of the study area (3), often attributable to improper wastewater treatment practices. A MDNR study attributed most well contamination in the area to the combination of improperly cased and sealed wells and barnyard runoff.

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*Cave dwelling organisms.

Those areas of Greene County most susceptible to ground water contamination (see Figure 13) have been delineated by Aley and Thomson (12). Factors affecting this susceptibility include: sinkhole development, faults and fractures in the bedrock, and specific soil types. The extremely high, and high risk areas warrant special precautions for wastewater collection and treatment systems.

Contaminants from wastewater discharged into aquifers may have potentially severe impacts on subterranean aquatic organisms. Troglobitic organisms are adapted to exist in a specialized niche in a stable environment. Seemingly minor changes to the quality of their environment may cause major impacts to the subterranean ecosystem. An increase in ground water BOD can cause underground streams to become anaerobic, with the resulting loss of the aquatic fauna. Instances of severely degraded or anaerobic springs and underground streams in the study area include Sequiota and Rader Springs.

Other contaminants harmful to aquatic life include residual chlorine, chlorinated organic by-products, ammonia-nitrogen, and heavy metals. The dissolved forms of such metals as copper, cadmium, chromium, lead, and zinc are toxic to aquatic life in varying degrees, and even at lower concentrations, may accumulate in the tissues of an organism until toxic levels are reached. Some of these metals (particularly copper and zinc) have been found at elevated concentrations in the underground stream flowing through Fantastic Caverns. Federal criteria (218) for protecting aquatic life from the toxic effects of copper and zinc list 24-hour maximum averages of 5.6 and 47 micrograms/liter, respectively. The maximum allowable concentration for each metal is dependent on the hardness of the water. (Water hardness tends to be inversely related to the toxicity of heavy metals to aquatic life.) According to these criteria, given an approximate total hardness of 190 mg/l at Fulbright Spring (13), the maximum allowable concentration for the protection of aquatic life from copper would be approximately 41 micrograms/liter, and from zinc, approximately 547 micrograms/liter.

Troglobitic aquatic animals are adapted to an environment that changes very slowly, over geologic time spans. Adaptations include: a loss of genetic variability; low growth, reproduction, and metabolic rates; and increased longevity* (143). Since troglobites are highly specialized, they are particularly sensitive to man-induced environmental impacts. Chronic exposure to low levels of dissolved heavy metals may cause changes in the mortality, reproductive success, and behavior of troglobites (219). Organisms tend to accumulate and concentrate heavy metals to which they are exposed. A study of two crayfish species in a Tennessee cave (one troglobitic, the other non-troglobitic or troglophilic) indicated that the troglobite accumulated twice as much cadmium and copper, and twelve times as much lead, as the less specialized (more adaptable) troglophilic crayfish (219). These increased concentrations probably were the result of a longer exposure time from increased longevity. The Tennessee study concluded that "the unique adaptations of troglobitic organisms may inhibit their ability to cope with chronic exposure to even low concentrations of toxic metals." Thus, heavy metal contamination of ground waters may pose special problems to troglobitic organisms, many of which are classified by state and federal authorities as endangered or threatened.

Other contaminants, e.g., 1,2-dichloroethylene and trichloroethylene (organic solvents commonly used in many industries), have also been found in measurable quantities in the surface and ground waters around Fantastic Caverns (220). One source of heavy metals and organic solvents contaminating the water in and around Fantastic Caverns was probably the wastewater treatment lagoons at Litton Systems, Inc. in northwest Springfield. On September 19, 1980, Litton Systems, Inc. was assessed a $20,000 civil penalty in the Greene County Court for violation of Missouri's Clean Water Law due to overflows into sinkholes and percolation of inadequately treated wastewater into ground waters (221). Dye tracing studies by the City of Springfield confirmed an underground hydrologic connection between sinkholes near Litton Systems, Inc., and several springs northwest of Springfield, including the stream in Fantastic Caverns (see Figure 12).

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* Evidence from a long-term study of a troglobitic crayfish species in Alabama indicates that they may live longer than a century (219).

Contaminants from treated wastewater effluents can also impact the aquatic ecology of surface waters. Chlorine residual from effluent disinfection can adversely impact aquatic life. Although other means of effluent disinfection are available, chlorination is widely used. For proper disinfection, domestic sewage treatment plants usually maintain a combined chlorine residual of 0.5 to 2.0 parts per million (ppm) (222). Fish are known to avoid sections of streams where the combined chlorine concentration is 0.37 ppm (222), while concentrations as low as 0.01 ppm may have detrimental effect on the survival and reproduction of aquatic life (223). The toxicity of chloramine, a combined form of chlorine, to two common aquatic organisms of Missouri has been studied. Crayfish (Orconectes nais) and orangethroat darters (Etheostoma spectabile) had a 96-hour LC_{50} (that concentration which killed 50 percent of the test organisms within a 96-hour exposure) of 0.76 and 0.39 ppm, respectively (224). Therefore, a stream with a small dilution capacity probably cannot support many organisms immediately below a WWTP with a chlorinated discharge. The downstream effects of chlorination will depend on a number of factors, including the volume and velocity of the stream flow, the actual chlorine concentration, and the volume of the discharge. The worst conditions would occur when a comparatively high volume effluent with a high chlorine concentration is discharged during low stream flow periods.

A major potential impact to the aquatic ecology (and indirectly, the water quality) concerns the increase in concentrations of plant nutrients (primarily nitrate-nitrogen and orthophosphate-phosphorus) caused by the discharge of nutrient-rich WWTP effluents. Man's activities can cause large increases in the nutrients available to aquatic plant life through the additions from agriculture and sewage effluents. According to the Missouri Department of Conservation, "A major source of nutrients reaching waterways in the United States is sewage from both municipal sewage treatment plants and unsewered residential areas (73)." High concentrations of these nutrients can stimulate excessive growth of many types of suspended (phytoplankton) and attached (periphyton) algae.

Algae populations can become so dense that the water begins to look like "pea soup." Algae and other types of aquatic plants can become so thick that they "carpet" lake or stream bottoms and other stationary objects, causing serious aesthetic impacts. Dense algal blooms can also lower the DO concentration and cause fish kills. Even though algae (like other green plants) produce oxygen under sunlight conditions, they continue to respire at night. This respiration, when multiplied by the tremendous number of algal cells present during a bloom, consumes large quantities of dissolved oxygen. Lethal conditions for aquatic life may be reached before sunrise reverses the deoxygenation process.

Another problem associated with high algal concentrations occurs when these waters are used for drinking water supplies. Taste and odor problems in the finished water can limit public acceptance of the drinking water, and require expensive treatment methods for control.

Impacts associated with elevated concentrations of plant nutrients can be particularly severe in a lake or reservoir system, due to nutrient trapping and release by the sediments and the relatively low flushing rates. Some adverse impacts to surface water quality in the study area from discharges high in plant nutrients are unavoidable. The relatively high clarity of the surface streams in the study area will allow rapid algal uptake of the nutrients, with correspondingly high algal populations. These nutrients, once added to the aquatic system, will continue to be recycled as the water proceeds downstream, until converted to another form of biomass (e.g., fish flesh) or lost to lake sediments. Since all of the streams in the study area flow through local or large downstream reservoirs, some increases in the eutrophication rates of the various affected reservoirs will occur. The increases to the large reservoirs should be minor, especially when compared to the existing nutrient levels and eutrophication rates. Discharges of WWTP effluents upstream from lakes or reservoirs should be avoided when possible, especially when the lake is a source of drinking water. Small increases in nutrients can have some beneficial impact by increasing the amount of food (algae) available to other organisms.

A minor beneficial impact on the water quality and aquatic ecology would be an increase in base flow of streams receiving discharges from proposed new municipal WWTPs. Small intermittent streams could support a much more diverse biota, given the steady input of adequately treated effluent.

2. Induced Growth

The primary water-quality-related impacts from induced growth result from changes in land use patterns. Increased commercial and residential development (partially resulting from improved wastewater collection and treatment facilities) will result in more paved areas (e.g., parking lots, roads, etc.), and thereby more urban runoff. The pollutants associated with urban runoff have been identified as a prime factor in past fishkills in the Wilsons Creek/James River system (40, 55).

Since sinkholes form a part of Springfield's storm drainage system (225), increased urban runoff will further degrade the existing poor ground water quality of the shallow aquifer (see Section II-C). Also, additional development in areas drained by sinkholes will increase the volume of storm runoff, thereby increasing the frequency and magnitude of sinkhole flooding.

Residential growth in the rural sections of the study area also has the potential to adversely affect ground water quality. Inadequate well construction practices may connect the upper and lower aquifers across the Northview Shale aquitard*, increasing the potential for further contamination of the lower aquifer. As previously stated, the Missouri Geological Survey recommends that new wells be cased through the Swan Creek Sandstone formation, to minimize the possibility of withdrawal from a contaminated aquifer or connecting two different quality aquifers.

3. Potential Wastewater System Failures

Constructing centralized wastewater collection and treatment facilities establishes the potential for failures in the collection network or at the treatment site. Impacts to the water quality and aquatic ecology of the study area from these failures could range from minor (sewage bypasses during storm runoff events) to severe (interceptor sewer rupture in a sinkhole area).

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*A formation which partially confines an aquifer, restricting water movement.

Both of the major Springfield WWTPs currently bypass incoming sewage when flows exceed their hydraulic capacities (42 MGD for the Southwest Plant and 5.25 MGD for the Northwest Plant) plus storage. Bypasses may continue at these and other WWTPs, or at overloaded pump stations in any proposed collection and treatment system during periods of high inflow and infiltration from storm events. Given the dilution potential of high stream flows under runoff conditions, infrequent bypasses of partially treated sewage (treated by settling and disinfection) should have minor water-quality-related impacts.

More serious potential impacts from centralized wastewater collection and treatment systems result from the Karst topography predominant in the study area. Severe ground water contamination has resulted from catastrophic collapses of treatment lagoons and interceptor or pipeline ruptures in several areas of the Ozarks.

The most recent example of a pipeline rupture occurred in November 1981 in an ammonia fertilizer pipeline near St. James, Missouri. The fertilizer entered the ground water by draining into a losing stream and depleted the dissolved oxygen, killing an unknown (but large) number of troglobites (Salem cave crayfish and southern cavefish). The anaerobic ground water surfaced at Meramec Spring and endangered the trout in a large state-run fish hatchery (226).

Similar impacts can result from leaking sewers and interceptors. A study in Eureka Springs, Arkansas found that leakage from sewer lines had contaminated (moderately to severely) 24 of 77 springs tested (227). Such leakage can be difficult to detect and may become a chronic source of ground water pollution.

Catastrophic collapses of treatment facilities have occurred in and near the study area. In 1968, a wastewater treatment lagoon in Republic drained when the bottom collapsed into a sinkhole (see Section II-C-2). In May 1978, a wastewater treatment lagoon at West Plains, Missouri collapsed, dumping approximately 25,000,000 gallons of sewage into the ground water. A localized epidemic of gastroenteritis resulted, with approximately 800 cases confirmed by the Missouri Division of Health (52).

4. Improved Wastewater Treatment Facilities

One of the major beneficial impacts on the water quality and aquatic ecology of the study area will be eliminating septic tank systems in some of the areas least suitable for this treatment type. Centralized wastewater collection and treatment systems in these areas should result in improved quality of surface water runoff and will help ensure that all wastewater receives adequate treatment. Eliminating failing septic systems should decrease the quantity and increase the quality of discrete ground water recharge.

Another beneficial impact of improved wastewater treatment facilities will be removing from service or renovating some of the presently inadequate treatment facilities. Fish kills in the Little Sac River should be eliminated or greatly reduced by expanding and upgrading the existing Springfield Northwest Plant, especially with the addition of a nitrification process (ammonia conversion to nitrate). Small or inadequate municipal or industrial WWTPs could also be included in a more efficient, centralized system. The suspected source of ground water contamination from the wastewater treatment lagoons at Litton Systems, Inc. was controlled by instead discharging to the Airport trunk sewer and the Northwest Plant.

5. Construction-Related Impacts

Several adverse temporary impacts are associated with construction activities for sewer lines or treatment plants. Installing new or parallel sewer lines in and adjacent to streambeds can result in a variety of negative impacts to the water quality and aquatic ecology of the stream. The most serious impact would be the silt load and turbidity introduced into the stream by sewer line construction. Although some additional silt load from sewer construction is unavoidable, large amounts of silt will suffocate most of the bottom-dwelling aquatic life and cause fish to seek more suitable habitat elsewhere.

Other impacts from sewer line construction in and adjacent to streambeds are more chronic and long-term. Varying amounts of streamside vegetation can be lost to construction activities, thereby increasing the amount of sunlight reaching the water. If enough vegetation is removed, water temperatures may increase to the point that the aquatic life cannot survive. Removing streamside vegetation and altering the flow pattern (with waterstops, rip-rap, or channelization) will also impact the aquatic life. These alterations reduce the diversity of specific habitats available for fish and other aquatic life. After the sewer line is constructed, the potential exists for incidents of stream pollution from leakage or rupture of the sewer line.

Water quality and aquatic ecology impacts may be particularly severe when construction occurs in or near the natural drainage channels of watersheds upstream from lakes and reservoirs. The effects of increased siltation on most of the fish in the lakes and reservoirs in the study area would be to lower reproductive success by smothering spawning sites with sediment, and to decrease growth rates by lowering the effectiveness of sight-feeding predators, such as largemouth bass and bluegill. Sewer line construction in such areas should be controlled to minimize erosion and sedimentation, and construction should be limited to the summer and fall after spawning is completed. Sewer line construction in and adjacent to streambeds should be viewed as an overall negative impact, with the severity depending on specific construction practices and amount of construction.

6. Threatened and Endangered Species

Discharges to and pollution of the Pomme de Terre River and various other Osage River basin streams would impact the Niangua darter (*Etheostoma nianguae*). Discharges to losing streams and ground water pollution could impact the Ozark cavefish (*Amblyopsis rosae*), the blind salamander (*Typhlotriton spelaeus*), and a blind, white crayfish (*Cambarus setosus*).

7. Mitigative Measures

Some design or construction modifications are available to mitigate the adverse impacts to the water quality and aquatic ecology from proposed project alternatives.

a. Contaminants in Wastewater Effluent. Many of the adverse water quality impacts from discharges of treated wastewaters may be mitigated by increasing the extent of treatment provided. However, additional treatment also increases costs. MDNR effluent limitations are designed (in part) to promote treatment effectiveness while minimizing costs, based on the size, assimilative capacity, and designated uses of the receiving stream.

Mitigative measures for two specific types of contaminant-induced impacts may warrant special consideration. Increased levels of plant nutrients from wastewater may cause increases in the algal populations and eutrophication rates of the area's streams and lakes. Specific treatment processes are available to reduce the nutrient concentrations in wastewater, but their high costs severely limit their use. Wastewater treatment with land application can divert plant nutrients in effluents away from the aquatic ecosystem. However, this treatment type has been found to be impractical in the area, due to limitations imposed by soil conditions and structural geology.

Impacts from wastewater disinfection with chlorine can be mitigated or eliminated by removing or changing the disinfection process, or by adding subsequent dechlorination. Those alternatives including a WWTP discharging disinfected effluent into either the Little Sac River or the Pomme de Terre River basins should include either a disinfection process that does not produce a chlorine residual, such as ozonation or disinfection with ultra-violet light, or a reliable system for removing chlorine residual (dechlorination). This requirement would reduce water-quality-related impacts to the Niangua darter and other aquatic life from discharges of treated municipal wastewater.

b. Induced Growth. Impacts resulting from induced growth can be minimized by strict adherence to Greene County's projected growth plans. Growth and development should be encouraged in those parts of the county best suited and equipped (i.e., schools, gas, water, roads, etc.) for development. Residential and, particularly, commercial and industrial development should not be encouraged in areas drained by sinkholes.

c. Potential Collection and Treatment Failures. Design options are available to mitigate water-quality-related impacts from wastewater collection and treatment failures. Impacts from wastewater bypasses or overflows at treatment plants or pump stations can be mitigated by adding or enlarging emergency storage basins in appropriate locations. Overflows can be stored in these basins and fed back into the treatment system, when peak flows subside or plant operations resume. Collection system studies and subsequent improvements to reduce excessive infiltration and inflow may be beneficial.

Auxiliary power generation at pump stations and treatment plants is an effective means of achieving system reliability. Key treatment and pumping systems should be designed with multiple units and sized such that an individual unit can be removed from service for maintenance or repair without serious loss of capacity and treatment effectiveness.

A severe potential impact to the water quality and consequently the aquatic life forms would be ground water contamination from a leaking or broken force main or interceptor sewer in a sinkhole plain or along a losing stream. Design options to mitigate this impact include:

- Rerouting facilities to avoid the high risk areas.
- Using pressure pipe, rather than conventional gravity sewers in high risk areas. Joints between pressure pipe sections are stronger and less prone to leak than those in a gravity line.
- Constructing the line using ductile iron pipe (rather than reinforced concrete, or plastic pipe) due to its properties of strength, flexibility, and availability of joints that will deflect.
- Incorporating a means of flow measurement to detect leakage or I/I.
- Installing remote telemetry equipment at pump stations to alert maintenance personnel in case of a force main rupture. This equipment could monitor pumpage rates or pressure to detect a major failure and allow maintenance staff to respond promptly.

d. Improved Wastewater Treatment Facilities. No negative impacts to water quality or aquatic ecology are associated with improving wastewater treatment facilities and thus no mitigative measures are applicable.

e. Construction-Related Impacts. The negative impacts to the water quality and aquatic ecology from sewer construction in and adjacent to streambeds or sinkholes should be mitigated by minimizing construction in these areas. All stream crossings for sewers or heavy equipment should be promptly returned to approximate preconstruction conditions. Special care should be given to preserving the natural vegetation along streams and around sinkholes, and to minimizing erosion in those basins upstream from Springfield's water supply intakes. Strict specifications requiring sediment control measures during construction (e.g., sediment traps or hay bales) should be included to minimize the amount of sediment washed into the streams, lakes, and underground channels of the planning area.

D. TERRESTRIAL ECOLOGY

The greatest impact on the terrestrial ecology will occur during the construction phase when interceptors and force mains are being laid. Construction equipment may clear as much as a 50-foot swath, the width of the temporary construction easement, depending on the type and size of pipe and terrain encountered. However, most construction impacts should generally be confined to a 30-foot width over the length of the line.

Regardless of the nature of disturbance, if vegetation is changed and habitat is altered, populations of some species may benefit, while others may be adversely affected. Primary impacts to the terrestrial ecology will be caused by the direct physical removal of the original vegetation. These impacts will be similar for each terrestrial community throughout the length of the construction easement. While the immediate impacts are locally severe, they are short-term. The impacts of this destruction of vegetation on wildlife can be summarized as follows:

- Destruction of the food source upon which herbivores (insects, rabbits, deer) depend;
- Destruction of cover upon which all wildlife species depend;
- Displacement of mobile wildlife species, i.e., most reptiles, birds, and mammals;
- Direct mortality of nonmobile species, i.e., burrowing amphibians, reptiles and mammals; nesting birds and mammals;

- Overcrowding and increased competition for resources on adjacent areas; and

- Decrease in nutrient and energy flow to adjacent areas.

Long-term impacts will be related to the manner and type of revegetation of the corridor. The degree of impact will be dependent on the value of the plant community or habitat type affected and its abundance in the study area. In Greene County, the most common habitats are pasture, cultivated fields, and urban areas which are generally of lower value. Unique or unusually productive habitats such as bottomland forest, old field, prairie, and wetlands are much more valuable for local plants and wildlife as well as having the potential to harbor threatened and endangered species. The recommended alternatives will occur primarily in urban areas, pasture, and, to a lesser extent, bottomland forest. Detailed descriptions of long-term impacts will be limited to these three communities, with less emphasis on the undisturbed communities.

1. Urban

The greatest area to be affected by the proposed construction involving the placement of interceptors and force mains will occur in the suburban areas on the periphery of the City of Springfield and in the towns of Battlefield, Brookline, Fair Grove, Republic, Strafford, Walnut Grove and Willard. Since much of the construction will be directed on existing road and utility rights-of-way, impacts on the urban habitat will be insignificant. Most impacts to the landscape will be readily mitigated since soil, grass, forbs, and plant materials other than large trees will be replaced following construction. Once plant materials have been successfully re-established, urban wildlife will return to these areas. Only those species that used large trees will experience a reduction in habitat along the right-of-way.

2. Pasture

The pasture and cultivated fields represent the second most acreage to be influenced by construction activities. Depending on the time of year, pastures can be productive within the same year following construction. Within two years, pastures should be capable of being grazed. Following construction, cultivated land should be left in such a condition that farming can proceed as before. Cultivated fields may lose some productivity in the immediate area of trenching due to the loss of the soil profile.

3. Bottomland Forests

Bottomland forests or riparian woodlands are critical to wildlife, especially in the growing Springfield suburban areas, where urban land uses have depleted most native habitats, but where vestiges of riparian woodlands remain. Short-term impacts on these areas will be restricted to force mains and interceptor rights-of-way that connect with pump stations or treatment plants situated in floodplains. Long-term impacts include the sites where pump stations and waste treatment plants will be constructed and maintained.

Removal of existing vegetation during construction will eliminate woodland-dwelling species from the corridor. If left undisturbed following construction, revegetation would proceed naturally through a series or succession of plant associations culminating with the climax or original bottomland forest. Community dominance usually changes from annual-perennial weeds to grasses, shrubs, and trees. The time frame varies depending upon site, climate, substrate, and seed sources, but typically shrubs are present after 10 years and trees after 20 years. Springfield Utilities does not have a planned vegetation management program over their permanent easements; however, they normally maintain an access right-of-way along the more urban locations. Therefore, natural succession in rural areas should proceed unhindered, while in more urban areas, the rights-of-way will be maintained as pasture or old field communities. Otherwise, the successional pattern will be interrupted only in the event of necessary repairs to the pipelines.

Following construction, each vegetative association of the bottomland forest community will provide habitat for new wildlife populations while eliminating others. Grass and forb species will soon cover the corridor, and populations of the short-tailed shrew, prairie meadow mouse, thirteen-lined ground squirrel, prairie white-footed mouse, and cottontail rabbit will increase. Small-mammal species diversity is highest during the grassland stage of succession. Conversely, when all but the herbaceous vegetation is removed from a riparian community, avian diversity will be greatly reduced. Birds inhabiting this association will include the song sparrow, field sparrow, goldfinch, and bobwhite. Many other mammals and birds will utilize this area for hunting food but will not dwell there.

As bushes and deciduous saplings enter the corridor, additional mammal species will be found, such as the eastern chipmunk, while the populations of species associated with herbaceous vegetation will decrease. This stage is marked by an increase in the number of bird species resulting from the increased structural diversity of the habitat. Birds now present include mostly edge or old field species including the yellow-billed cuckoo, gray catbird, cardinal, and mockingbird.

When trees become large enough for wildlife use, a different complement of species will be noted. Many of the grassland species will be eliminated, but mammals like the white-footed mouse, gray and fox squirrels, opposum, and raccoon will replace them. Diversity of bird species will be at its peak in this association. Woodpeckers will begin to use the woods again, insect-eating warblers will be spring visitors, and the black-capped chickadee, tufted titmouse, and eastern wood pewees will be residents.

In the final or climax stage of the bottomland woodlands community, mature trees will form a closed canopy, reducing the lower levels of vegetation and thereby decreasing diversity. As snags form in mature trees, cavity-nesting species such as woodpeckers and screech owls will once again be present. Mast (nuts and acorns) produced by oaks and hickories will provide a good food source for mice, squirrels, chipmunks, turkeys, and deer in the climax forest.

4. Wetlands, Caves and Natural Areas

Aside from the bottomland forests, now classified as wetlands by the U.S. Fish & Wildlife Service, no other wetlands will be affected by construction activities. No known caves or natural areas will be directly impacted by construction. It is possible, however, that work occurring in the vicinity of very permeable soils or sinkholes will result in a turbid condition in waters of cave systems and aquifers.

Impacts to cave biota will largely be contingent upon the duration and severity of the event. These impacts should be of short duration and their effect on cave biota are expected to be negligible.

5. Threatened and Endangered Species

No adverse impacts are expected to state or federal threatened and endangered plant or terrestrial wildlife species from the implementation of any of the recommended alternatives.

6. Mitigative Measures

Impacts to urban areas which have been disturbed by construction will be mitigated by replacing the soil, covering bare areas by seeding with grass or by sod, fertilizing, and landscaping the disturbed area with plant materials similar to those removed by construction. In areas presently devoted to agricultural activities, acreage will be graded to permit reuse of these lands. Bottomland forest cleared for the right-of-way will be graded and reseeded naturally from adjacent vegetation. It is recommended that construction in bottomland forest occur during the winter months to avoid disruption of newborn wildlife during the spring and summer and to permit an entire growing season for recovery of denuded rights-of-way.

E. AIR QUALITY AND NOISE

1. Air Quality

Short-term adverse air pollution effects are caused by construction vehicle emissions and dust from excavation work. Construction activities will take place over the 20-year planning period and will be concentrated along interceptors, trunk lines, and force main routes, at new or modified treatment plants and pump stations, and in areas of new collection systems.

Greene County is an attainment area for air pollution parameters (meeting National Ambient Air Quality Standards), and construction impacts are not expected to significantly reduce air quality. Construction impacts will not be of long duration in any one area.

No beneficial or adverse long-term air quality impacts are expected from operating collection and treatment facilities. Future incineration or co-incineration for sludge volume reduction at Springfield could have a potentially significant impact, but these alternatives are not within the scope of current facilities planning.

2. Odors and Aerosols

Odors from construction equipment will be insignificant, and no major adverse or beneficial construction impacts are expected.

Odors may occur from surfacing septic tank systems and holding basins, lift stations, and treatment plants if sewage is retained for prolonged periods of time in the collection system and turns septic. Mechanical breakdown, overloading, or other treatment plant upsets may result in odors. Important factors include the duration of a breakdown, waste loadings, and climatic conditions. Such upsets will have a short-term adverse effect on the surrounding community.

Odors from wastewater treatment plant sludges may be a problem if the sludges are not properly processed and disposed. Odors from land spreading of sludge will occur if the sludge is not adequately stabilized and not incorporated into the soil.

Wastewater treatment lagoons may cause odor problems, particularly during periods of thermal overturn or destratification, overloading, following algal blooms, or when ice cover breaks up releasing gaseous products from anaerobic decomposition. Odors may be strong near outfalls where turbulence releases dissolved gases.

Odor problems can be reduced or eliminated by sewering areas with failing septic tank systems. Upgrading or retiring inadequate or poorly operated treatment facilities will also provide a long-term benefit. Odor problems from inadequate on-site or small systems will continue during the planning period and increase under no-action alternatives.

Liquid aerosols are generated at wastewater treatment plants by aeration, spray irrigation, and other processes that discharge tiny droplets into the atmosphere. Pathogens and other pollutants may be present in aerosols. No evidence has been found that aerosols have affected the health of wastewater facilities personnel or others, but proper buffer zones should be provided to prevent exposure of the general public (228).

3. Noise

Construction of sewer systems and treatment facilities will create unavoidable, temporary noise impacts. Noise from construction equipment and blasting along sewer routes will be annoying to local residents and temporarily disturb wildlife in the vicinity of proposed sewer routes and treatment plant sites. Low level noises from operation of pump stations and treatment facilities will not cause adverse long-term impacts to residents or wildlife.

4. Mitigative Measures

a. Air Quality. If construction coincides with dry, windy periods, dust may be a potential problem where equipment and vehicles operate, particularly in open areas. Construction areas should be sprinkled during these periods to reduce dust. Exhaust emissions from construction equipment should be minimized by thorough equipment maintenance.

b. Odor. Strict adherence to good operations and maintenance practices is the best means of preventing or eliminating odor problems at sewage treatment plants. Chlorination, aeration, or other means of oxidizing sewage in problem areas of wastewater collection systems will help to control odors caused by septic conditions.

c. Noise. Construction equipment should be equipped with adequate mufflers, especially when working in developed areas. Construction activities in developed areas should be confined to daylight hours. Blasting should also be limited to daylight hours, regardless of location, and should be preceeded by an effective public information program to notify and warn residents.

F. CULTURAL RESOURCES

1. Impacts on Archaeological Resources

The construction of wastewater treatment facilities in Greene County is expected to have short-term and long-term impacts on archaeological resources. The effects may be partially or completely destructive, and four types of impacts are identified.

a. Land Application Systems. Application of wastewater and sludge to cultivated land is not expected to impact artifacts and will still allow future archaeological survey. Since large amounts of phosphate will be deposited, and phosphate is one means of locating prehistoric human activity, application of this survey method will be negated. Construction of storage lagoons and buried lines associated with land application of wastewater may disturb or destroy archaeological sites.

b. Sewer Lines. Cutting a trench through an archaeological site destroys the integrity of the entire site because each part is interrelated. Soils and alluvial deposits in Greene County are relatively shallow, thus any sewer line is likely to disturb any buried as well as surface archaeological materials.

c. Wastewater Treatment and Pumping Facilities. Partial site damage or complete destruction may occur at treatment plant and pump station sites.

d. Secondary Impacts from Urbanization. Development of wastewater facilities will tend to encourage private development of areas served, and this will impact archaeological resources. Most of these long-term, secondary impacts will not involve Federal financial support and most site destructions will occur without mitigative plans.

2. Impacts on Historic Resources

Compared to the larger number of prehistoric sites that may be impacted, few direct impacts to historic resources are anticipated. However, indirect impacts that are very difficult to foresee are likely to affect many historic sites. Four types of impacts are discussed.

a. Land Application Systems. Land application will affect few, if any, historic structures. Applied phosphate will negate phosphate analysis as a means of locating historic archaeological site boundaries.

b. Sewer Lines. Sewer lines serve and therefore affect the built environment by definition. Most sewers will be placed along existing streets and roadways, and not affect historic resources although buried historic resources, such as cobblestone streets and antebellum structures, could be encountered. Sewer lines which cut across open landscape or follow stream courses may encounter historic resources. Cutting a sewer trench through a historic archaeological site destroys the integrity of the entire site because each part is interrelated.

c. Wastewater Treatment and Pumping Facilities. Like sewer lines, treatment plant and pump station construction is not likely to impact large numbers of buildings. Archaeological historic sites might be impacted in the same manner as prehistoric sites.

d. Secondary Impacts from Urbanization. Development of wastewater facilities will tend to encourage private development of areas served, and this will impact the built environment. Since there are no formal written records of much of the historic built environment, information from material, evidence, written records, and human memory can be lost.

3. Mitigative Measures

Mitigation of sewer line trench impacts to prehistoric or historic archaeological sites would require surface collection or testing of the entire site to obtain a notion of its internal composition. Buried portions of significant sites that would be destroyed could be salvaged by excavation. Partial site damage from construction of treatment plant and pumping facilities could be mitigated in the same way. In instances of complete destruction of a site determined to be significant, a research strategy for site salvage would be developed. The strategy would detail the kinds of significant information to be recovered and selected research questions. It would be impossible to recover all information from a site.

To mitigate long-term secondary impacts from development, a regional approach to survey and mitigation should be taken during project planning and construction. In this way, knowledge gained from exploring prehistoric and historic sites destroyed or damaged by construction can be applied to sites destroyed later by secondary impacts. Construction contract documents should require the contractor to halt operations and notify the SMSU Center for Archaeological Research or the Missouri Archaeological Society whenever archaeological remains are discovered during excavation.

G. POPULATION

Sewer construction is not expected to have an impact on the total growth of the planning area or a large impact on the total growth of subareas. At these levels the impacts of wastewater facility decisions will be small relative to the larger economic forces determining population growth. The impact of sewer construction will be felt on a more localized scale, i.e., along transportation corridors, areas zoned for commercial or industrial uses, or in new residential developments within subareas. The most important impact of sewer construction will be in permitting higher residential densities, or influencing the residential distribution within subareas.

Assessment of secondary impacts resulting from induced growth must consider that sanitary sewers alone are generally not sufficient to bring about residential (or other) development in undeveloped areas. The availability of water, electricity, natural gas, and roads is at least as important. The availability and quality of schools, the natural attractiveness of the area, and people's perceptions of an area are other influencing factors. An important factor in controlling development is the existence of zoning ordinances and/or health regulations which prohibit or restrict development in specific areas. However, in the absence of these social control measures and of any public investments, development can occur if pressures are sufficient.

Where on-site wastewater disposal problems become severe and widespread, residential and commercial growth, property values, and the tax base could be negatively affected. In general, the more widespread the problem of wastewater disposal in the subarea, the greater is the likelihood of these impacts occurring. Conversely, the more geographically limited the wastewater disposal problem, the lesser the impacts. Quantification of these impacts is difficult because exact relationships between wastewater disposal problems and growth and development have not been established.

H. ECONOMICS AND FINANCING

1. Economic Conditions

Several economic benefits could accrue to the local economy from sewerage facility construction. The first of these is the potential for an increase in jobs and income during the construction phase of the project. This benefit would generally be minimal, but because of the scope of the proposed projects in Greene County, and the likely phasing of improvements, semi-permanent construction jobs could result.

The second benefit is that new sewerage facilities construction may make some previously unsewered areas more attractive for industrial development if other development factors are favorable. These factors include relatively flat land, good rail and highway access, compatible adjacent land uses, and a favorable investment climate. As with residential development, many factors besides the availability of sewers influence the location of industrial facilities.

2. System Financing

a. Grants

1) Grants from the Federal Government. The federal government, through EPA's Municipal Wastewater Facilities Construction Grants Program, will pay 75 percent of the eligible costs associated with wastewater treatment (includes the treatment plant, lift stations, and associated force mains and interceptor sewers), and 85 percent for projects using "innovative and alternative" technology, for grant assistance awarded before October 1, 1984. Interim final rules for 40 CFR Part 35, which cover the construction grants program, were published in Volume 47, Number 92 of the Federal Register, dated May 12, 1982. These rules specify that after September 30, 1984, the federal share will decrease from 75 to 55 percent for conventional projects, and from 85 to 75 percent for innovative and alternative technology. Alternatives and projects recommended in Section III and associated annual costs are given without consideration of grant funding levels.

The decrease in the level of federal funding will have the effect of increasing user cost for those projects funded after the September 30, 1984, deadline. The increased user cost will result primarily from debt service on the larger community share of the construction cost.

A system classified by the federal government as "innovative and alternative," such as land application of effluent, provides some financial benefits to the local community which may outweigh uncertainty over the system's performance or reliability. Such systems would allow a lower local contribution than conventional systems of comparable or even slightly greater present worth, which would allow lower user charges. Under the new funding levels, innovative or alternative technology will receive federal funding of an additional 20 percent of the eligible project costs, rather than the current 10 percent, making its use cost-effective for a wider range of applications.

2) Eligible Project Costs. Treatment plants, pump stations, force mains, and interceptor sewers are generally eligible for federal grant participation, as are various costs related to subagreements, mitigation, privately or publicly owned small and on-site systems, and real property, and equipment, materials, and supplies. Lateral and collector sewers are not normally grant eligible; nor are the costs for additional capacity in treatment plants and interceptors to serve future growth., Non-conventional collection systems, such as pressure sewers, may be fundable as innovative and alternative technology. A list of grant-eligible costs is included in Appendix A of 40 CFR Part 35, as published in Volume 47, Number 92 of the Federal Register. Appendix A states that eligible costs are not limited to those listed, but additional eligibility determinations will be made on a project-by-project basis consistent with applicable laws and regulations.

3) State Grants and Priority List. The Missouri Clean Water Commission has a program to provide additional grant funds. On October 1, 1984, the federal grant share will be reduced from 75 percent to 55 percent of eligible costs for conventional technology and from 85 percent to 75 percent for innovative and alternative projects. The state grant share before October 1, 1984 is 15 percent for conventional technology and 9 percent for innovative and alternative technology. After the federal reduction, the state share will be increased to 25 percent for conventional technology and 15 percent for innovative and alternative technology. These funds apply to the same eligible items as the federal grant.

In addition, the Missouri Clean Water Commission administers a new state construction grant program where federal funding is not involved. This program allows the state to make 55 percent grants to communities for wastewater facilities. The grant amount is limited to $500,000 per year for communities with a service area of less than 500,000 persons.

The amount of federal and state money available to fund the construction grants program is quite limited relative to the number of projects for which federal assistance is sought. To ensure that the available money is spent on the most serious water quality problems, the State of Missouri maintains a priority list which ranks the projects seeking funding on a variety of factors, including population affected, public health hazards, water quality problems, and others. Because of the many projects throughout the state attempting to obtain federal and state funding, and the reduced levels of funding currently available, many of the projects recommended for implementation in Greene County will probably not be able to obtain federal or state grant assistance.

User costs that could be expected with federal and state grant assistance are presented in Table 41. The impact of the estimated user charge for each subarea, as compared to the EPA threshold percentage for determining whether a project is considered expensive, is indicated in Table 42. All projects for the unsewered communities are very expensive in terms of user charges and economic impact. Without grant assistance, user charges would be even higher. User costs for Republic and Springfield will remain well below the EPA threshold percentage.

I. GOVERNMENT AND COMMUNITY SERVICES

Extending interceptors into areas currently served by septic systems will allow more dense, compact development on adjacent undeveloped land due to smaller allowable lot sizes. This should result in a more efficient provision of community services. Conversely, extending interceptors into areas not planned for growth during the planning period may result in population shifts to these areas, resulting in an inefficient provision of community services.

Capital improvement planning and the provision of community services can be made more effective by locating utilities to complement planned growth. The mitigation of wastewater facilities impacts on the environment requires coordinating various growth-regulation tools. Since a variety of factors work together to shape the man-made environment, adjustments to a wastewater treatment facilities plan may not be enough to prevent or significantly reduce negative impacts. Other

TABLE 41
ESTIMATED USER CHARGES

Community	Community Share to Finance[a]	Average Annual User Charges[b]	One-Time Hook-Up Fee
Battlefield	$1,511,000	$746	$368
Brookline	628,000	813	164
Fair Grove	1,622,000	756	410
Republic	1,100,000	140	15
Springfield	4,000,000	84	--
Strafford	1,907,000	846	358
Walnut Grove	857,000	807	307
Willard	2,038,000	807	400

(a) Based upon estimated costs for 1984-1985. Republic and Springfield Northwest Plant costs are based on pre-October 1984 Federal and State grant contributions for eligible items; others are based on grant contributions that apply after October 1984.

(b) In 1934-1985 dollars and based on revenue bond amortization at 10 percent annual interest over a 20-year period. The payments cover bond retirement and an additional 30 percent bond reserve fund plus operation and maintenance costs.

TABLE 42
USER CHARGES/HOUSEHOLD INCOME COMPARISON

Community	1980 Median Household Annual Income[a]	Average Annual User Cost[b]	User Cost Percent of Median Household Annual Income	EPA Threshold Percentage (1980 Income)
Battlefield	$22,218	$533	2.4	1.75
Brookline	18,267	581	3.2	1.75
Fair Grove	15,488	683	4.4	1.5
Republic	17,451	130[c]	0.7[c]	1.75
Springfield	14,881	84[d]	0.6[d]	1.5
Strafford	14,897	604	4.1	1.5
Walnut Grove	10,477	577	5.5	1.5
Willard	17,755	577	3.2	1.5

(a) 1979 income multiplied by Consumer Price Index factor of 1.135.

(b) 1984-1985 user charges of Table 41 adjusted to 1980 dollars.

(c) Costs of new and existing facilities, including current charges of about $2.50 per month, depending on metered water use.

(d) Costs for new and existing facilities including current average charges of about $6.40 per month.

growth-regulation tools at the disposal of local government include the comprehensive plan, the zoning ordinance, subdivision regulations, water system extensions, and roadway improvements. If these tools are coordinated, negative impacts are more effectively avoided or minimized.

Potential future impacts may be mitigated by updating the comprehensive plan on a regular basis, and reviewing the recommendations for future sewer developments contained in the Facilities Plan. Where necessary, the Facilities Plan should be updated to reflect the revised comprehensive plan.

J. EXISTING WASTEWATER TREATMENT SYSTEMS

Central wastewater collection and treatment systems and new interceptor lines will eliminate many small treatment and pump station facilities. Regional alternatives for treating wastewaters from the Brookline, Battlefield, Strafford, and Willard subareas at Springfield's Northwest or Southwest treatment plants will have a significant impact on short- and long-term planning for these facilities. It is especially important to consider impacts on the Northwest Plant system which is smaller than the Southwest plant system and in imminent need of expansion and replacement. Although firm commitments and agreements for serving the outlying subareas can probably not be realized at the Facilities Planning stage, providing coordinated planning and flexibility to serve these areas will be important to future implementation.

K. ENERGY AND OTHER RESOURCES

Energy in the form of hydrocarbon fuels and electricity is required in manufacturing the products used to construct the wastewater collection and treatment facilities, including the energy used during construction. Other resources used include metals for reinforcing, structural steel, pumps, and machinery; plastics for piping and equipment; and sand, crushed rock, and cement for concrete and bedding. Although some metals and other materials can be recycled, the cost recovery is likely to be small, and it is assumed that the commitment of material and energy resources is not recoverable.

Energy is also a very important consideration in operating wastewater systems since large amounts are often needed for pumping, aeration, and sludge processing. The energy costs are detailed in the Facilities Plan O&M costs of the various alternatives and are thus an important factor in determining cost-effectiveness. Recovery of energy from sludges may also be feasible, such as the process of anaerobic digestion with methane gas recovery used at the Southwest Treatment Plant.

The "no-action" alternative is the only mitigation measure for the consumption of energy and other resources used in construction. Energy efficient process selection and collection and treatment system design are very important for reducing energy consumption and costs during long-term operation. Land application of sludge is a means of using nutrient and soil conditioning values for crop production.

L. LAND USE

1. Interceptors Serving Undeveloped Areas

Undeveloped parts of subareas may become more attractive to developers if interceptors pass through these areas. If the comprehensive plan does not provide for future development in these areas, orderly growth may be difficult to achieve, and the timely provision of community services may be difficult to coordinate.

Residential developments utilizing individual septic systems are generally developed at a lower density than developments served by sewerage facilities due to minimum lot-size requirements as prescribed by zoning ordinances. Providing sewers for such areas means that adjacent undeveloped land can be developed at a greater density, allowing for more efficient provision of community services.

2. Land Use Impact of Treatment Facilities

Development, especially residential, around treatment facilities may be impacted by the fact that such facilities may be an eyesore to some people, or may be the source of foul odors. Wastewater treatment facilities recommended for construction in the Facilities Plan are proposed to be built either immediately adjacent to existing wastewater treatment plants or in areas considered undesirable for other development or not critical for agricultural use.

M. SOLID WASTE

Sludge processing and disposal often represents a large part of treatment plant facilities and operating costs and are considered in the Facilities Plan alternatives analyses for cost-effectiveness. Where practical, land application is a useful means of sludge disposal that avoids utilizing landfill capacity and recycles nutrient and soil conditioning values to farmland.

V. SPECIFIC IMPACTS

This section identifies the specific impacts that can be expected to occur with each of the alternatives described in Section III. The impacts within the general categories discussed in Section IV are summarized for each subarea within the planning area, and the significant impacts are further discussed. Matrices for each subarea provide a summary of the beneficial or adverse environmental effects and constraints for each of the wastewater collection and treatment alternatives. The effects are rated from (+2) for the most beneficial impact to (-2) for the most adverse impact. The ratings are qualitiative and generally meant to distinguish a minor (±1) or major (±2) impact. No entry in the matrix indicates the alternative would have no appreciable effect on a particular category. The various impacts have not been weighted relative to each other since the importance of different impact categories may differ widely among different alternatives and different segments of the public.

A wide variety of impacts can be expected from the Facilities Plan alternatives in each of the study area subareas. Many of the impacts are beneficial and typical of sewerage projects in urban and suburban areas. A number of very sensitive environmental resources are also affected.

Specific cultural resources impacts are based upon surveys conducted in the vicinity of the proposed wastewater facilities, particularly where landforms are favorable for sites. The surveys were conducted during the summer of 1983 by the Center for Archaeological Research, SMSU. The surveys discovered 15 prehistoric sites, 1 prehistoric/historic site, and 4 isolated finds within or near the project areas. Ten sites appear to contain potentially important information, and are assessed as potentially eligible for inclusion in the National Register of Historic Places (164).

This section addresses those Facilities Plan alternatives and recommendations which may have potentially significant adverse impacts. Many of the recommendations discussed in this section are not definite

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proposals for immediate action. It is quite possible that some factors bearing on these recommendations, or on their potential impacts, could change significantly in the next few years, with corresponding changes in this analysis.

A. SPRINGFIELD SUBAREA

1. Southern System

Possible wastewater management improvement alternatives for the southern system are still in preliminary planning stages, but could provide significant environmental benefits. Additional sludge stabilization prior to land spreading will reduce odor problems and complaints from nearby residents and help to assure that land continues to be made available by local farmers for this purpose.

Effluent reuse by the City Utilities Southwest Power Plant could improve the ultimate quality of the effluent discharge and of the receiving stream through advanced treatment, including nutrient removal. Since Wilsons Creek is a losing stream, further treatment or effluent diversion directly to the James River could also benefit ground water quality. The potential adverse effects on water quality and aquatic ecology of any chemical additives for control of cooling water system fouling, as well as heat load and other pollutants of concern, would require mitigation. Heating of oxygenated, ozone-treated effluent or of the receiving waters could result in significant oxygen losses. Less oxygen will dissolve in warm water than in cold water and supersaturation and oxygen loss could thus occur with increased water temperature. A significant potential benefit is the conservation of high quality ground (or surface) water supply resources that could be used for purposes other than serving future power plant expansion.

A sewer system evaluation survey (SSES)* would be beneficial in determining how to cost-effectively control the most serious I/I problems of the southern system, and control or reduce collection and treatment system overflows.

The longer-range decision on whether to expand the Southwest Treatment Plant or build a new James River basin plant should not have a

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*A study to identify specific problems where excessive I/I are indicated.

SPRINGFIELD SUBAREA - SOUTHERN SYSTEM

Alternatives	Wastewater Management				Collection System							
	1*	2*	3*	4	1N	1*	2N	2*	3N	3*	4N	4*
IMPACTS												
Geology and Soils												
- Soils Suitability					-1		-1		-1		-1	
- Soils Disturbance						-1		-1		-1		-1
- Slope					-1	-1	-1	-1	-1	-1	-1	-1
- Loss of Prime Farmland				-1		-1		-1		-1		-1
- Increased Soils Erosion						-1		-1		-1		-1
- Shallow Bedrock					-1	-1	-1	-1	-1	-1	-1	-1
- Bedrock Fractures					-1	-1	-1	-1	-1	-1	-1	-1
- Sinkholes												
- Rock Excavation						-1		-1		-1		-1
Water Resources												
- Flooding												
- Base Stream Flow												
- Ground Water Supply		+2										
Water Quality and Aquatic Ecology												
- Surface Water Quality, Overall		+1			-2	+2	-2	+2	-2	+2	-2	+2
- Surface Water Quality, Receiving Stream		+1				-1		-1		-1		-1
- Ground Water Quality		+1			-2	+2	-2	+2	-2	+2	-2	+2
- Chlorine Residual Toxicity												
- Eutrophication Potential		+1			-1	+1	-1	+1				
- Troglobitic Species					-1	+1	-1	+1	-1	+1	-1	+1
- Rare/Endangered Species												
- Increased Urban Runoff						-1		-1		-1		-1
- Eliminate Septic System Problems					-2	+2	-2	+2	-2	+2	-2	+2
- Turbidity from Construction						-1		-1		-1		-1
- Improved Treatment		+1	+1	+1			-2	+2	-2	+2	-2	+2
- Losing Stream		+1			-2	+2						
- Surface Water Supply					-2	+2						
Terrestrial Ecology												
- Loss of Habitat						-1		-1		-1		
Atmosphere												
- Air Quality Degradation												
- Septic System Odors					-1	+1	-1	+1	-1	+1	-1	+1
- Collection and Treatment Odors	+2											
Cultural Resources												
- Prehistoric Sites Potential				-2		-2		-1				
- Historic Sites Potential				-1								

SPRINGFIELD SUBAREA - SOUTHERN SYSTEM (continued)

	Wastewater Management				Collection System							
Alternatives	1*	2*	3*	4	1N	1*	2N	2*	3N	3*	4N	4*
Population												
- Unanticipated Shifts						+1		+1		+1		+1
- Growth						+1		+1		+1		+1
Economics and Financing												
- Construction Employment			+1	+1		+1		+1		+1		+1
- Industrial Development			+1	+1		+1		+1		+1		+1
- User Charges			-1	-1		-1		-1		-1		-1
- Community Financing Ability		-1	-1	-1		-1		-1		-1		-1
Community Services												
- Efficient Expansion						+2		+2		+2		+2
Existing Wastewater Systems												
- Efficient Expansion	+1		+1	+1		+2		+2		+2		+2
Land Use												
- Planning Compatibility	+1			-1		+2		+2		+2		+2
- Aesthetics	+1			-1		+1		+1		+1		+1

ALTERNATIVES:

Wastewater Management

1 - Sludge stabilization.*
2 - Effluent reuse.*
3 - Expand Southwest Treatment Plant to handle James River system wastes.*
4 - Construct new James River system plant.

Collection System

1N - Pierson Creek basin - no action.
1 - Pierson Creek basin collection facilities.*
2N - James River basin - no action.
2 - James River basin collection facilities.*
3N - Ward Branch basin - no action.
3 - Ward Branch basin collection facilities.*
4N - Wilsons Creek basin - no action.
4 - Wilsons Creek basin collection facilities.*

* Proposed or recommended in the Draft Facilities Plan.

major differential impact on water quality of Wilsons Creek and the James River. A new James River basin plant would mean that about 5 MGD of comparably treated effluent would be discharged directly to the James River rather than to the James River via Wilsons Creek. A wasteload allocation study would be required to determine the effect of shifting this load and not using the assimilative treatment capacity provided by Wilsons Creek. The possible benefit of removing this wasteload from Wilsons Creek, a losing stream, should also be considered. Although the James River below Lake Springfield is not a losing stream or classified for whole-body contact recreation, disinfection and ammonia removal would be required at a James River basin plant to meet current effluent requirements. A new James River basin plant could have significant adverse impacts on land uses in the plant vicinity as well as archaeological resources at the plant site and along the one-mile force main from the James River pump station to the plant. Significant land use and archaeological resource impacts are not anticipated for the Southwest Treatment Plant expansion alternative.

The collection system alternatives for the southern system are compatible with land use planning to serve prime development areas. Numerous small wastewater treatment and pumping facilities will be eliminated and developments now on dead sewers will be served. Significant adverse impacts from construction include erosion and turbidity from streambed construction, disturbance of archaeological resources, and loss of bottomland wildlife habitat. Individual lines with 10 to 25 percent of their alignment through bottomland woods are the Pierson Creek interceptor, P-3, P-9, J-1, Thompson Branch interceptor, and WB-3.

The Pierson Creek basin facilities will help protect the water quality at Springfield's James River water supply intake. The Pierson Creek and Thompson Branch facilities will also reduce eutrophication potential of Lake Springfield. The collection facilities will have a beneficial impact on present and future James River water quality and ground water quality.

An archaeological survey of the proposed Thompson Branch trunk route revealed prehistoric sites 23GR551 and 23GR552. Site 23GR551 consists of a light scatter of chert artifacts while site 23GR552 consists of some shovel tested chert flakes. There is no evidence of habitation at either site and they are not considered potentially significant. Survey of the Pierson Creek interceptor extension route revealed prehistoric site 23GR550 consisting of a light scatter of chert artifacts. Based on artifacts recovered from the site by others, site 23GR550 is a multi-component site containing Paleo through Late Woodland occupation and is potentially eligible for inclusion in the National Register of Historic Places (164). An archaeological survey and plans to mitigate the impacts of previously designed Pierson Creek interceptor facilities have been done in the past. No action has been taken on the recommended mitigation measures. The interceptor extension alignment should be modified to avoid this site. There are no other previously recorded prehistoric or historic cultural resources within the proposed southern system construction areas.

2. Northern System

Replacing the existing Northwest Treatment Plant with a new and expanded advanced treatment facility downstream is needed because the existing facility is becoming overloaded and was not designed to meet current effluent requirements. The existing plant is not suitable for continued use and expansion because of severe site flooding problems, the structural problems of constructing plant additions on a landfill area, and the need for extensive facilities rehabilitation.

Alternative No. 1, no action, would continue operation of the existing plant and is rated "unacceptable." Alternative Nos. 2 and 3 are both rated "good" and will benefit water quality and aquatic ecology of the Little Sac River and South Dry Sac Creek. A replacement plant at either site would remove the effluent discharge to South Dry Sac Creek, a losing stream.* Alternative No. 2 is proposed in the Draft Facilities Plan because of site problems of shallow rock and steeper slopes with

* Reevaluation of the Missouri Geological Survey indicates that South Dry Sac Creek below the Northwest Treatment Plant is not losing; this information was reported subsequent to the Draft Facilities Plan.

SPRINGFIELD SUBAREA - NORTHERN SYSTEM

Alternatives	Northwest Plant					S. Dry Sac Interceptor	
	1	2*	3	4	5	1	2*
IMPACTS							
Geology and Soils							
- Soils Suitability					-2	-2	
- Soils Disturbance		-1	-1				-1
- Slope			-2		-1		
- Loss of Prime Farmland		-1	-1				-1
- Increased Soils Erosion		-1	-1				-1
- Shallow Bedrock			-2		-2		
- Bedrock Fractures	-1	-1	-1	-1	-2		
- Sinkholes					-2		
- Rock Excavation			-2				
Water Resources							
- Flooding	-2			-2			
- Base Stream Flow		-1	-1		-1		+1
- Ground Water Supply							
Water Quality and Aquatic Ecology							
- Surface Water Quality, Overall	-2	+2	+2	+1	+1	-2	+2
- Surface Water Quality, Receiving Stream	-2	+2	+2	+1	+2	-2	+2
- Ground Water Quality	-2	+2	+2	+1	+1	-2	+2
- Chlorine Residual Toxicity	-1	+1	+1	-1			
- Eutrophication Potential							
- Troglobitic Species	-1	+1	+1	+1	+1	-1	+1
- Rare/Endangered Species							
- Increased Urban Runoff							
- Eliminate Septic System Problems	-1	+1	+1	+1	+1	-2	+2
- Turbidity from Construction		-1	-1				-1
- Improved Treatment	-2	+2	+2	+1	+2		
- Losing Stream	-2	+2	+2	-1	+2	-2	+2
- Surface Water Supply						-2	+2
Terrestrial Ecology							
- Loss of Habitat							-1
Atmosphere							
- Air Quality Degradation							
- Septic System Odors	-1	+1	+1	+1	+1	-1	+1
- Collection and Treatment Odors	-1						
Cultural Resources							
- Prehistoric Sites Potential		-2	-2		-2		-2
- Historic Sites Potential		-1	-1		-1		-1

SPRINGFIELD SUBAREA - NORTHERN SYSTEM (continued)

Alternatives	Northwest Plant					S. Dry Sac Interceptor	
	1	2*	3	4	5	1	2*
Population							
- Unanticipated Shifts							
- Growth		+1	+1	+1	+1		+1
Economics and Financing							
- Construction Employment		+1	+1	+1	+1		+1
- Industrial Development		+1	+1	+1	+1		+1
- User Charges		-1	-1	-1	-2		-1
- Community Financing Ability		-1	-1	-1	-1		-1
Community Services							
- Efficient Expansion		+1	+1	+1	+1		+1
Existing Wastewater Systems							
- Efficient Expansion	-2	+1	+1	-2			+1
Land Use							
- Planning Compatibility	-2	+2	+2	+2	-2	-2	+2
- Aesthetics	-2	+2	+2	+2	+2		

ALTERNATIVES:

Northwest Treatment Plant

1. Northwest Treatment Plant remains as it is (no action).
2. Northwest Treatment Plant relocation to the Murray site.*
3. Northwest Treatment Plant relocation to the Highway 13 site.
4. Expansion and upgrading of existing plant.
5. Land application.

South Dry Sac Branch Interceptor

1. No South Dry Sac interceptor (no action).
2. Construct South Dry Sac interceptor.*

* Proposed in the Draft Facilities Plan.

Alternative No. 3. Because the Alternative No. 2 and 3 sites are 15,000 and 10,000 ft, respectively, downstream of the existing plant, the adverse impacts of further extending the plant interceptor along the Little Sac River will be somewhat greater for Alternative No. 2. Adverse impacts to archaelogical resources, prime farmland, and bottomland woods, and added stream turbidity and soil erosion from construction would occur along the interceptor alignment. Removing effluent from the reach of stream below the existing Northwest Plant to the proposed site would reduce the dry weather streamflow available for aquatic life and livestock watering. (The upstream water supply reservoirs already affect streamflows in this reach.)

The proposed South Dry Sac interceptor system is compatible with land use planning to serve prime development areas. Several small wastewater pump stations will be eliminated. Significant adverse impacts from construction include erosion and turbidity from streambed construction, disturbance of archaeological resources, and loss of bottomland wildlife habitat. The South Dry Sac interceptor will benefit the longer-term water quality of South Dry Sac Creek, including Valley Water Mill, a component of Springfield's water supply sources.

An archaeological survey of the proposed South Dry Sac interceptor route revealed eleven prehistoric sites: 23GR539, 23GR540, 23GR541, 23GR542, 23GR543, 23GR544, 23GR545, 23GR546, 23GR547, 23GR548, and 23GR549. Seven of the sites, as underlined above, are potentially eligible for inclusion in the National Register of Historic Places. Site 23GR539 is along a cut bank of the South Dry Sac River, where chert flakes were recovered from 12 to 28 inches below ground surface. Sites 23GR40 and 23GR44 consist of moderate and light scatter, respectively, of chert artifacts. Site 23GR546 and 23GR547 are close together and probably closely related. Site 23GR546 consists of light to moderate scatter of chert artifacts and probably served as a field camp and knapping station, tentatively during the Late Archaic and Early Woodland period. Site 23GR548 is in the vicinity of Valley Water Mill and consists of a light to moderate scatter of chert artifacts, and is affiliated with the Late Woodland period. Site 23GR549 consists of a light to moderate scatter of chert artifacts and may be affiliated with the Middle Woodland period. The interceptor alignment should be modified to avoid these sites, or, if avoidance is not possible, test excavations should be conducted to determine their significance. There are no other previously recorded prehistoric or historic archaeological sites within the proposed construction areas.

An archaeological survey of the Little Sac interceptor route (from the existing Northwest Treatment Plant to the proposed Murray site) and new plant site revealed six archaeological sites. Five prehistoric sites are located on terraces near the river and are assessed as potentially eligible for inclusion in the National Register of Historic Places. Site 23GR535 has a Middle Woodland occupation, 23GR536 has a Late Woodland occupation, and no affiliation has been determined for sites 23GR532, 23GR533, and 23GR537. Site 23GR534 is a historic roadbed and bridge abutment which is assessed as ineligible for inclusion in the National Register. The project should be modified to avoid the prehistoric sites, or, if avoidance is not possible, test excavations should be conducted to determine their significance.

B. BATTLEFIELD SUBAREA

The Battlefield area contains fragipan soils in upland areas, and highly permeable soils with possible gravel lenses are found in the valley alluvium. Sinkholes and losing streams are found in the area. The soils and geological problems result in "unacceptable" negative impacts and limitations for continued long-term use of on-site systems (no action) or land application treatment. Effective on-site system management programs to upgrade and control the design, construction, and operation of these systems and to reduce flow or otherwise modify wastewater characteristics would be an alternative to mitigate the adverse impacts of no action.

Alternative No. 3 with a treatment plant discharging to the James River and Alternatives No. 4 and 5 conveying wastes to the Springfield southern system are rated "fair." The James River basin plant would result in the average year 2005 flow of about 0.6 MGD being

BATTLEFIELD SUBAREA

Alternatives	1	2	3	4*	5	6
IMPACTS						
Geology and Soils						
- Soils Suitability	-2					
- Soils Disturbance		-1	-1	-1	-1	-1
- Slope						
- Loss of Prime Farmland		-1				
- Increased Soils Erosion					-1	
- Shallow Bedrock						
- Bedrock Fractures	-2	-1	-1	-1	-1	-2
- Sinkholes	-2	-1	-1	-1	-1	-2
- Rock Excavation						
Water Resources						
- Flooding		-2				
- Base Stream Flow		+1				
- Ground Water Supply						
Water Quality and Aquatic Ecology						
- Surface Water Quality, Overall	-2	+2	+2	+2	+2	+2
- Surface Water Quality, Receiving Stream		-2	-1	-1	-1	
- Ground Water Quality	-2	+1	+2	+2	+2	+1
- Chlorine Residual Toxicity		-1	-1			
- Eutrophication Potential						
- Troglobitic Species	-1					
- Rare/Endangered Species						
- Increased Urban Runoff						
- Eliminate Septic System Problems	-2	+2	+2	+2	+2	+2
- Turbidity from Construction					-1	
- Improved Treatment						
- Losing Stream		-2		-1	-1	
- Surface Water Supply						
Terrestrial Ecology						
- Loss of Habitat					-1	
Atmosphere						
- Air Quality Degradation						
- Septic System Odors	-1					
- Collection and Treatment Odors						
Cultural Resources						
- Prehistoric Sites Potential		-2	-2	-2	-2	-2
- Historic Sites Potential		-1	-1		-1	-1

BATTLEFIELD SUBAREA (continued)

Alternatives	1	2	3	4*	5	6
Population						
- Unanticipated Shifts						
- Growth	-1	+1	+1	+1	+1	+1
Economics and Financing						
- Construction Employment		+1	+1	+1	+1	+1
- Industrial Development		+1	+1	+1	+1	+1
- User Charges		-2	-2	-2	-2	-2
- Community Financing Ability		-2	-2	-2	-2	-2
Community Services						
- Efficient Expansion						
Existing Wastewater Systems						
- Efficient Expansion				+1	+1	
Land Use						
- Planning Compatibility		+1	+1	+1	+1	+1
- Aesthetics	-1					

ALTERNATIVES:

1. No action.
2. Indian Springs Branch treatment plant.
3. James River treatment plant.
4. Regional pump station to James River pump station.*
5. Regional pump station to Southwest Treatment Plant.
6. Land application.

* Proposed in the Draft Facilities Plan.

discharged directly to the James River rather than to the James River via Wilsons Creek. A wasteload allocation study would be required to determine the effect of shifting this load and not using the assimilative treatment capacity provided by Wilsons Creek. The possible benefit of removing this wasteload from Wilsons Creek, a losing stream, should also be considered. Although the James River below Lake Springfield is not a losing stream or classified for whole-body contact recreation, disinfection and ammonia removal would be required at the James River plant to meet current effluent requirements. The James River plant could have significant adverse impacts on archaeological resources at the plant site and along the plant influent and effluent lines. The force main to the Southwest Treatment Plant could have significant adverse impacts on archaeological resources and bottomland woods wildlife habitat along Wilsons Creek.

An archaeological survey of the route of the force main to the James River pump station (Alternative 4) revealed prehistoric site 23GR553. A light to moderate scatter of artifacts, possibly Early Archaic, was found, and the site is potentially eligible for inclusion in the National Register of Historic Places (164). The force main alignment should be modified to avoid this site. There are no other previously recorded prehistoric or historic archaeological sites within the proposed construction areas.

Alternative No. 2, the Indian Springs Branch treatment plant, is rated "poor" because of the potential impacts of discharging to a losing stream, particularly a stream not currently receiving effluent. The Indian Springs Branch plant could have significant adverse impacts on archaelogical resources at the plant site and along the plant influent line.

All central collection and treatment alternatives will result in very high user charges and will be difficult for the City of Battlefield to finance, even with grant assistance.

C. BROOKLINE SUBAREA

The Brookline area residual soils are highly permeable, but because most have a fragipan layer, septic system effluent surfacing is a serious problem. Extensive sinkhole development and shallow and pinnacled bedrock are typical of the area. The creeks in the area are losing streams. These soils and geological problems result in an "unacceptable" rating because of adverse impacts to surface and ground water quality from continued long-term use of on-site systems (no action) or from land application. Since development density and projected growth for the Brookline subarea are low, the potential adverse impacts of no action are proportionately less severe. Effective on-site system management programs to upgrade and control the design, construction, and operation of these systems and to reduce flow or otherwise modify wastewater characteristics would be an alternative to mitigate the adverse impacts of no action.

Alternative No. 2, a treatment plant discharging to Pond Creek, is rated "poor" because of the potential impacts of discharging to a losing stream, particularly, a stream not currently receiving effluent. Alternative Nos. 3 and 4, pumping to Republic and Springfield, respectively, are rated "poor" and "fair", respectively. Based upon the alternative proposed for Republic in the Draft Facilities Plan, Alternative No. 3 would result in significant additional discharge to Dry Branch and Pickerel Creek, both losing streams, and a significant additional loading on the Republic treatment system. The effect on Wilsons Creek, also a losing stream, and the Southwest Treatment Plant is judged to be less significant because of the larger scale and proven performance of the existing treatment facilities. The annual equivalent cost of pumping to Springfield is also estimated to be significantly less. All central collection and local or regional treatment alternatives will result in very high user charges and will be difficult for the City of Brookline to finance, even with grant assistance. An archaeological survey of the proposed pump station site and previously recorded information did not reveal any cultural resources that would be affected by the proposed project (164).

BROOKLINE SUBAREA

Alternatives	1	2	3	4(a)	5
IMPACTS					
Geology and Soils					
- Soils Suitability	-2				
- Soils Disturbance		-1	-1	-1	-1
- Slope					
- Loss of Prime Farmland		-1			
- Increased Soils Erosion					
- Shallow Bedrock	-1	-1	-1	-1	-1
- Bedrock Fractures	-2	-1	-1	-1	-2
- Sinkholes	-2	-1	-1	-1	-2
- Rock Excavation		-1	-1	-1	-1
Water Resources					
- Flooding					
- Base Stream Flow		+1	+1		
- Ground Water Supply					
Water Quality and Aquatic Ecology					
- Surface Water Quality, Overall	-1	+1	+1	+1	+1
- Surface Water Quality, Receiving Stream		-1	-1		
- Ground Water Quality	-1	+1	+1	+1	+1
- Chlorine Residual Toxicity		-1	-1		
- Eutrophication Potential					
- Troglobitic Species	-1				
- Rare/Endangered Species					
- Increased Urban Runoff					
- Eliminate Septic System Problems	-1	+1	+1	+1	+1
- Turbidity from Construction		-1	-1	-1	-1
- Improved Treatment					
- Losing Stream		-2	-2(b)	-1	
- Surface Water Supply					
Terrestrial Ecology					
- Loss of Habitat					
Atmosphere					
- Air Quality Degradation					
- Septic System Odors	-1				
- Collection and Treatment Odors					
Cultural Resources					
- Prehistoric Sites Potential		-1	-1		-1
- Historic Sites Potential		-1	-1		-1

BROOKLINE SUBAREA (continued)

Alternatives	1	2	3	4(a)	5
Population					
- Unanticipated Shifts					
- Growth	-1				
Economics and Financing					
- Construction Employment		+1	+1	+1	+1
- Industrial Development		+1	+1	+1	+1
- User Charges		-2	-2	-2	-2
- Community Financing Ability		-2	-2	-2	-2
Community Services					
- Efficient Expansion					
Existing Wastewater Systems					
- Efficient Expansion				+1	
Land Use					
- Planning Compatibility				+1	
- Aesthetics	-1				

ALTERNATIVES:

1. No action.
2. Pond Creek treatment plant, sites 1 through 6.
3. Regional pump station to Republic.
4. Regional pump station to Springfield.(a)
5. Land application.

(a) Proposed in the Draft Facilities Plan.

(b) Depends upon Republic alternative; based upon alternative proposed in Draft Facilities Plan.

D. FAIR GROVE SUBAREA

The Fair Grove area has thin soil cover and in some locations the slopes are steep. The silty clay soils require low wastewater application rates to avoid effluent surfacing or runoff. These problems result in an "unacceptable" rating and negative impacts to surface and ground water quality for continued long-term use of on-site systems (no action). Effective on-site system management programs to upgrade and control the design, construction, and operation of these systems and to reduce flow or otherwise modify wastewater characteristics would be an alternative to mitigate the adverse impacts of no action.

Each of the discharge alternatives would impact the Niangua darter (Etheostoma nianguae), a small, bottom-dwelling fish listed as "rare" by the Missouri Department of Conservation and under study by the U.S. Fish and Wildlife Service for listing as "threatened." The upper Pomme de Terre River in Greene and Polk counties supports one of only eight known populations of this fish (152). The impact of Alternative No. 2 with a discharge directly to the Pomme de Terre River (downstream of the Highway E bridge) would be particularly damaging. This river reach possesses a particularly large and thriving population of Niangua darters (229). Alternative No. 2 is rated "unacceptable" due to the chronic or acute water quality impacts from a discharge of chlorinated-treated effluent (if dechlorination is inadequate) and the potential discharge of untreated or poorly-treated effluent in the event of other treatment system upset or the overflow and bypassing of raw sewage. Alternative Nos. 3 and 4 which discharge to tributaries of the Pomme de Terre River are rated "fair." (Providing dechlorination or an alternate disinfection process, such as ultra-violet light disinfection, is being considered for Alternative #3 since the discharge point is only about one mile above the confluence with the Pomme de Terre River.)

All central collection and treatment alternatives will result in very high user charges and will be difficult for the town of Fair Grove to finance, even with grant assistance. The land application alternative is not cost-effective compared to treatment and discharge alternatives and would result in a loss of over 13 acres of prime farmland required for the aerated lagoon and storage basin.

FAIR GROVE SUBAREA

Alternatives	1	2	3(a)	4	5	6
IMPACTS						
Geology and Soils						
- Soils Suitability	-2					-1
- Soils Disturbance		-1	-1	-1	-1	-1
- Slope				-2		
- Loss of Prime Farmland		-1	-1	-1		-1
- Increased Soils Erosion						
- Shallow Bedrock	-2	-2		-2		-2
- Bedrock Fractures						
- Sinkholes						
- Rock Excavation		-1		-1		-1
Water Resources						
- Flooding						
- Base Stream Flow		+1	+1	+1	+1(b)	
- Ground Water Supply						
Water Quality and Aquatic Ecology						
- Surface Water Quality, Overall	-1	+1	+1	+1	+1	+1
- Surface Water Quality, Receiving Stream	-1	-1	-1	-1	-1(b)	
- Ground Water Quality	-1	+1	+1	+1	+1	+1
- Chlorine Residual Toxicity		-2	-1	-1	(b)	
- Eutrophication Potential						
- Troglobitic Species						
- Rare/Endangered Species		-1	-1	-1	-1(b)	
- Increased Urban Runoff						
- Eliminate Septic System Problems	-1	+1	+1	+1	+1	
- Turbidity from Construction						
- Improved Treatment						
- Losing Stream					(b)	
- Surface Water Supply					(b)	
Terrestrial Ecology						
- Loss of Habitat						
Atmosphere						
- Air Quality Degradation						
- Septic System Odors	-1					
- Collection and Treatment Odors					-1	
Cultural Resources						
- Prehistoric Sites Potential		-1	-1	-1	-1	-1
- Historic Sites Potential		-1	-1	-1	-1	-1

FAIR GROVE SUBAREA (continued)

Alternatives	1	2	3(a)	4	5	6
Population						
- Unanticipated Shifts						
- Growth						
Economics and Financing						
- Construction Employment		+1	+1	+1	+1	+1
- Industrial Development		+1	+1	+1	+1	+1
- User Charges		-2	-2	-2	-2	-2
- Community Financing Ability		-2	-2	-2	-2	-2
Community Services						
- Efficient Expansion						
Existing Wastewater Systems						
- Efficient Expansion						
Land Use						
- Planning Compatibility						
- Aesthetics	-1					

ALTERNATIVES:

1. No action.
2. Pomme de Terre River treatment plant, site 1.
3. Pomme de Terre River tributary treatment plant, site 2A.(a)
4. Little Pomme de Terre River treatment plant, site 3.
5. Regional pump station to Strafford.
6. Land application.

(a) Proposed in the Draft Facilities Plan.

(b) Depends upon Strafford alternative; based upon alternative proposed in Draft Facilities Plan.

An archaeological survey of proposed routes of some collection system components and the Pomme de Terre River tributary treatment plant site (prior to revision of the site since the Draft Facilities Plan) revealed prehistoric site 23GR538 along a proposed force main route. The site consists of a light scatter of chert artifacts, suggestive of the Late Woodland period, and is potentially eligible for inclusion in the National Register of Historic places (164). Force main alignment should be modified to avoid this site. There are no other previously recorded prehistoric or historic archaeological sites within the proposed construction areas.

E. REPUBLIC SUBAREA

Soils and geology in the Republic area have severe limitations for septic systems, land application, and lagoon treatment systems. Because of these problems and deficiencies of the existing treatment system, the no action and land application alternatives are rated "unacceptable." A regional treatment plant on Shuyler Creek or McElhaney Branch is rated "poor" because of discharge to a losing stream that does not now receive effluent and very high costs.

A new plant at the existing Dry Branch plant site is rated "fair." Although there would be continued discharge to a losing stream, improvement of effluent quality to meet losing stream standards and elimination of the existing lagoons with their potential for catastrophic collapse will greatly benefit both surface and ground water quality. This alternative is compatible with efficient expansion of the existing system at a low cost relative to the other alternatives. A regional pump station to the Springfield southern system is not feasible because of high cost. An archaeological survey of proposed routes of some collection system components and the existing treatment plant site, as well as previously recorded information, did not reveal any cultural resources that would be affected by the proposed project (164).

REPUBLIC SUBAREA

Alternatives	1	2a	2b*	2c	3	4	5
IMPACTS							
Geology and Soils							
- Soils Suitability	-2	-2	-1				-2
- Soils Disturbance		-1	-1	-1	-1	-1	-1
- Slope	-2	-1	-1	-1	-1	-1	-2
- Loss of Prime Farmland							
- Increased Soils Erosion							-1
- Shallow Bedrock	-2				-1	-1	-2
- Bedrock Fractures							
- Sinkholes	-2	-1	-1	-1	-1	-1	-2
- Rock Excavation					-1	-1	-2
Water Resources							
- Flooding							
- Base Stream Flow	+1	+1	+1	+1	+1		
- Ground Water Supply							
Water Quality and Aquatic Ecology							
- Surface Water Quality, Overall	-2	+2	+2	+2	+2	+2	+2
- Surface Water Quality, Receiving Stream	-2	+2	+2	+2	-1	-1	
- Ground Water Quality	-2	+2	+2	+2	+2	+2	+2
- Chlorine Residual Toxicity		-1	-1	-1	-1	-1	
- Eutrophication Potential							
- Troglobitic Species	-1	+1	+1	+1	+1	+1	+1
- Rare/Endangered Species							
- Increased Urban Runoff							
- Eliminate Septic System Problems		+1	+1	+1	+1	+1	+1
- Turbidity from Construction					-1	-1	
- Improved Treatment		+2	+2	+2	+2	+2	+2
- Losing Stream	-2	-1	-1	-1	-1	-1	
- Surface Water Supply							
Terrestrial Ecology							
- Loss of Habitat							
Atmosphere							
- Air Quality Degradation							
- Septic System Odors							
- Collection and Treatment Odors							
Cultural Resources							
- Prehistoric Sites Potential					-1	-1	-1
- Historic Sites Potential							

REPUBLIC SUBAREA (continued)

Alternatives	1	2a	2b*	2c	3	4	5
Population							
- Unanticipated Shifts						+1	
- Growth	-1						
Economics and Financing							
- Construction Employment							
- Industrial Development							
- User Charges		-1	-1	-2	-2	-2	-2
- Community Financing Ability		-1	-1	-2	-2	-2	-2
Community Services							
- Efficient Expansion							
Existing Wastewater Systems							
- Efficient Expansion	-1	+1	+1	+1		+1	
Land Use							
- Planning Compatibility							
- Aesthetics							

ALTERNATIVES:

1. No action.
2a. New treatment plant at existing Dry Branch site, minimum project.
2b. New treatment plant at existing Dry Branch site, city limit project.*
2c. New treatment plant at existing Dry Branch site, subarea project.
3. Shuyler Creek or McElhaney Branch regional treatment plant.
4. Regional pump station to Springfield.
5. Land application.

* Proposed in the Draft Facilities Plan.

F. STRAFFORD SUBAREA

Soils in the Strafford area are generally silty clays with a fragipan layer and clay-rich soils below. The deeper clay soils are highly permeable in an undisturbed condition due to the natural soil structure and high stone content. Fragipan layers, if present, cause high runoff and low infiltration. Where construction penetrates the fragipan, the underlying permeable soils and bedrock allow rapid infiltration into the aquifer. The area is also susceptible to sinkhole collapse, particularly where the soil is thickest. These problems result in "unacceptable" limitations and negative impacts to surface and ground water quality for continued use of on-site septic systems (no action) or land application. Effective on-site system management programs to upgrade and control the design, construction, and operation of these systems and to reduce flow or otherwise modify wastewater characteristics would be an alternative to mitigate the adverse impacts of no action.

Wastewater collection and treatment alternatives in the Strafford subarea pose the most complex environmental issues in the planning area, and water quality and aquatic ecology effects are critical. Other than high user charges and financing difficulty, no major adverse environmental impacts should result from Alternative No. 8, the force main to Springfield's southern system. This alternative is rated "good."

Alternative No. 6, discharging to the Pomme de Terre basin below the local lake impoundments is rated "fair." The stream is not losing but, since the time the Draft Facilities Plan was released, MDNR has determined that discharge to the South Fork of the Pomme de Terre River will require disinfection for protection of whole-body contact recreation. Dechlorination would also be required to protect aquatic life since the streamflow is permanent with limited dilution factor. This discharge alternative would not affect a water supply watershed, but does impact the Niangua darter (Etheostoma nianguae). The upper Pomme de Terre River in Greene and Polk counties supports one of only eight known populations of this fish (152). Impacts from the discharge

STRAFFORD SUBAREA

Alternatives	1	2	3	4	5	6*	7	8*	9	10
IMPACTS										
Geology and Soils										
- Soils Suitability	-2									
- Soils Disturbance		-1	-1	-1	-1	-1	-1	-1	-1	-1
- Slope		-2	-2							-1
- Loss of Prime Farmland		-1	-1	-1	-1	-1	-1			-1
- Increased Soils Erosion									-2	
- Shallow Bedrock										
- Bedrock Fractures		-2	-2	-2	-2		-2			-2
- Sinkholes				-1	-2					-1
- Rock Excavation										
Water Resources										
- Flooding										
- Base Stream Flow		+1	+1	+1	+1	+1	+1			
- Ground Water Supply										
Water Quality and Aquatic Ecology										
- Surface Water Quality, Overall	-2	+2	+2	+2	+2	+2	+2	+2	+2	+2
- Surface Water Quality, Receiving Stream		-1	-1	-1	-1	-1	-1			
- Ground Water Quality	-2	+1	+1	+1	+2	+2	+2	+2	+2	+1
- Chlorine Residual Toxicity		-1	-1	-1	-2		-1			
- Eutrophication Potential					-1	-1	-2			
- Troglobitic Species	-1	-1	-1	-1	+1	+1	+1	+1	+1	+1
- Rare/Endangered Species					-1	-1				
- Increased Urban Runoff									-1	
- Eliminate Septic System Problems	-2	+2	+2	+2	+2	+2	+2	+2	+2	+2
- Turbidity from Construction		-1	-1	-1	-1	-1	-1	-1	-2	-1
- Improved Treatment										
- Losing Stream		-2	-2	-2					-1	
- Surface Water Supply	-2	-2	-2	-2			-2		-1	
Terrestrial Ecology										
- Loss of Habitat			-1						-1	
Atmosphere										
- Air Quality Degradation										
- Septic System Odors	-1									
- Collection and Treatment Odors								-1	-1	
Cultural Resources										
- Prehistoric Sites Potential		-1	-1	-1	-1	-1	-1	-1	-2	-1
- Historic Sites Potential		-1	-1	-1	-1	-1	-1	-1	-2	-1

STRAFFORD SUBAREA (continued)

Alternatives	1	2	3	4	5	6*	7	8*	9	10
Population										
- Unanticipated Shifts									-1	
- Growth	-1	+1	+1	+1	+1	+1	+1	+1	+1	+1
Economics and Financing										
- Construction Employment		+1	+1	+1	+1	+1	+1	+1	+1	+1
- Industrial Development		+1	+1	+1	+1	+1	+1	+1	+1	+1
- User Charges		-2	-2	-2	-2	-2	-2	-2	-2	-2
- Community Financing Ability		-2	-2	-2	-2	-2	-2	-2	-2	-2
Community Services										
- Efficient Expansion										
Existing Wastewater Systems										
- Efficient Expansion								+1	+1	
Land Use										
- Planning Compatibility		-1	-1	-1	-1	-1	-1	-1	-1	-1
- Aesthetics	-1									

ALTERNATIVES:

1. No action.
2. Pierson Creek treatment plant.
3. Davis Creek treatment plant.
4. Broad Creek treatment plant.
5. South Fork Pomme de Terre Treatment plant, Site #1.
6. South Fork Pomme de Terre treatment plant, Site #2 or Union 76 site*.
7. Little Sac River treatment plant.
8. Pumping to Springfield southern system.*
9. Pierson Creek gravity sewer to Springfield southern system.
10. Land application.

* Alternative 6 was proposed in the Draft Facilities Plan, but Alternative 8 is currently proposed because of objections to Alternative 6.

of treated wastewater from Strafford would include settling of suspended solids, deoxygenation from remaining oxygen demanding constituents (BOD), and increased algal populations resulting from plant nutrients in the effluent. These impacts would be relatively minor from properly treated effluent; however, the potential impact in the event of serious treatment system upsets, inadequate dechlorination, or the overflow and bypassing of raw sewage would be severe. The discharge alternative to the Pomme de Terre above the local lake impoundments is less desirable because of the potential lake eutrophication in addition to the impacts on the Niangua darter.

Several other discharge alternatives are rated "poor" because of impacts on losing streams, the water supply sources for Springfield, and archaelogical resources. Pierson Creek, Davis Creek, and Broad Creek are losing streams and upstream from the City of Springfield's water supply intake on the James River. The Pierson Creek gravity sewer, Alternative No. 9, would likely have major impacts on archaeological resources and might encourage unplanned growth in the upper Pierson Creek watershed. Discharge to the Little Sac River (Alternative No. 6) could add significantly to the rate of eutrophication of McDaniel and Fellows lakes. These are important water supply sources for Springfield and this alternative is rated "unacceptable."

All central collection and treatment alternatives will result in very high user charges and will be difficult for the town of Strafford to finance, even with grant assistance. An Archaeological survey of proposed routes of some collection system components and the Union 76 treatment plant site, as well as previously recorded information, did not reveal any cultural resources that would be affected by the proposed project (164) (prior to changing the proposed alternative since the Draft Facilities Plan).

G. WALNUT GROVE SUBAREA

The Walnut Grove area has thin soil cover and the soils have slow percolation rates. The streams have low flow and some are losing.

WALNUT GROVE SUBAREA

Alternatives	1	2	3(a)	4	5	6
IMPACTS						
Geology and Soils						
- Soils Suitability	-2					-1
- Soils Disturbance		-1	-1	-1	-1	-1
- Slope						
- Loss of Prime Farmland		-1	-1	-1		
- Increased Soils Erosion		-1	-1	-1	-1	-1
- Shallow Bedrock	-2	-1		-1	-1	
- Bedrock Fractures	-2	-1				-1
- Sinkholes			-1			
- Rock Excavation		-1				
Water Resources						
- Flooding						
- Base Stream Flow		+1	+1	+1	+1	
- Ground Water Supply						
Water Quality and Aquatic Ecology						
- Surface Water Quality, Overall	-1	+1	+1	+1	+1	+1
- Surface Water Quality, Receiving Stream		-1	-1	-1	-1	
- Ground Water Quality	-1					-1
- Chlorine Residual Toxicity		-1	-1	-1		
- Eutrophication Potential						
- Troglobitic Species						
- Rare/Endangered Species		-1	-1	-1		
- Increased Urban Runoff						
- Eliminate Septic System Problems						
- Turbidity from Construction						
- Improved Treatment						
- Losing Stream		-2(b)	-2	-2(b)		
- Surface Water Supply						
Terrestrial Ecology						
- Loss of Habitat						
Atmosphere						
- Air Quality Degradation						
- Septic System Odors	-1					
- Collection and Treatment Odors						
Cultural Resources						
- Prehistoric Sites Potential						
- Historic Sites Potential		-1		-1	-1	-1

WALNUT GROVE SUBAREA (continued)

Alternatives	1	2	3(a)	4	5	6
Population						
- Unanticipated Shifts						
- Growth						
Economics and Financing						
- Construction Employment		+1	+1	+1	+1	+1
- Industrial Development						
- User Charges		-2	-2	-2	-2	-2
- Community Financing Ability		-2	-2	-2	-2	-2
Community Services						
- Efficient Expansion						
Existing Wastewater Systems						
- Efficient Expansion						
Land Use						
- Planning Compatibility						
- Aesthetics	-1					

ALTERNATIVES:

1. No action.
2. Unnamed creek treatment plant.
3. Sugar Creek treatment plant(a).
4. Turkey Creek treatment plant.
5. Pump station to Ash Grove.
6. Land application.

(a) Proposed in the Draft Facilities Plan.

(b) Possible losing stream characteristics of the recieving stream are being reevaluated.

Sinkholes are found in some areas. These soils and geological problems result in an "unacceptable" rating and adverse impacts to surface and ground water quality for continued long-term use of on-site systems (no action) or for land application. Since development density and projected growth for the Walnut Grove subarea are low, the potential adverse impacts of no action are proportionately less severe. Effective on-site system management programs to upgrade and control the design, construction, and operation of these systems and to reduce flow or otherwise modify wastewater characteristics would be an alternative to mitigate the adverse impacts of no action.

Alternative No. 2, a treatment plant discharging to an unnamed tributary of Turkey Creek is rated "fair", although possible losing stream conditions need to be further investigated. Since the time the Draft Facilities Plan was released, the Missouri Geological Survey determined that Sugar Creek is a losing stream. Alternatives Nos. 3 and 4, treatment plants discharging to Sugar Creek and Turkey Creek, respectively, are rated "unacceptable." Turkey Creek is also a losing stream. Each of the discharge alternatives impact small streams that might be inhabited by the Niangua darter (Etheostoma nianguae). Pumping wastewater to Ash Grove is rated "fair", but costs are significantly higher than for the Turkey Creek and Sugar Creek treatment plants.

All central collection and treatment alternatives will result in very high user charges and will be difficult for the City of Walnut Grove to finance, even with grant assistance. An archaeological survey of the Sugar Creek treatment plant site and previously recorded information did not reveal any cultural resources that would be affected by the initially proposed project (164).

H. WILLARD SUBAREA

The Willard area has thin soil cover, fragipan soils, sinkholes, losing streams, and flood-prone areas. These problems result in an "unacceptable" rating and negative impacts to surface and ground water quality for continued use of on-site systems (no action), and also

WILLARD SUBAREA

Alternatives	1	2	3	4	5*	6
IMPACTS						
Geology and Soils						
- Soils Suitability	-2					
- Soils Disturbance		-1	-1	-1	-1	-1
- Slope						
- Loss of Prime Farmland		-2				
- Increased Soils Erosion		-1	-1	-1	-1	-1
- Shallow Bedrock				-2		
- Bedrock Fractures						
- Sinkholes	-2			-1	-1	-2
- Rock Excavation				-2	-1	
Water Resources						
- Flooding						
- Base Stream Flow		+1	+1	+1	+1	
- Ground Water Supply						
Water Quality and Aquatic Ecology						
- Surface Water Quality, Overall	-2	+2	+2	+2	+2	+2
- Surface Water Quality, Receiving Stream		-1		-1		
- Ground Water Quality	-2	-1		-1		-1
- Chlorine Residual Toxicity		-1		-1		
- Eutrophication Potential						
- Troglobitic Species	-1	-1		-1	-1	
- Rare/Endangered Species		-1				
- Increased Urban Runoff						
- Eliminate Septic System Problems		+1	+1	+1	+1	+1
- Turbidity from Construction		-1	-1	-1	-1	-1
- Improved Treatment						
- Losing Stream		-2		-2		
- Surface Water Supply						
Terrestrial Ecology						
- Loss of Habitat						
Atmosphere						
- Air Quality Degradation						
- Septic System Odors	-1					
- Collection and Treatment Odors					-1	
Cultural Resources						
- Prehistoric Sites Potential		-2	-1	-1	-1	-1
- Historic Sites Potential		-1	-1	-1	-1	-1

WILLARD SUBAREA (continued)

Alternatives	1	2	3	4	5*	6
Population						
- Unanticipated Shifts						
- Growth	-1					
Economics and Financing						
- Construction Employment		+1	+1	+1	+1	+1
- Industrial Development		+1	+1	+1	+1	+1
- User Charges		-2	-2	-2	-2	-2
- Community Financing Ability		-1	-1	-1	-1	-2
Community Services						
- Efficient Expansion						
Existing Wastewater Systems						
- Efficient Expansion					+1	
Land Use						
- Planning Compatibility			-1	-1	-1	
- Aesthetics	-1					

ALTERNATIVES:

1. No action.
2. Asher Creek treatment plant.
3. Little Sac River treatment plant.
4. Little Sac River tributary treatmant plant.
5. Regional pump station to Springfield.[a]
6. Land application.

*Proposed in the Draft Facilities Plan. Some impacts depend upon Springfield northern system alternatives; based upon alternative proposed in the Draft Facilities Plan.

make land application impractical. Effective on-site system management programs to upgrade and control the design, construction, and operation of these systems and to reduce flow or otherwise modify wastewater characteristics would be an alternative to mitigate the adverse impacts of no action.

Alternative No. 3, a new wastewater treatment plant on the Little Sac River, is rated "good" and would have no major adverse environmental impacts. Alternative No. 5, a regional pump station to Springfield's northern system is rated "fair." This alternative would be rated "good" except that there is potential for severe ground water contamination from sewer line collapse or leakage as the proposed force main crosses the extensive sinkhole plain between Willard and Springfield.

Alternatives No. 2, a treatment plant on Asher Creek, and No. 4 would discharge to losing streams and are rated "unacceptable." These alternatives would impact troglobitic species and Alternative No. 2 would impact the Niangua darter (*Etheostoma nianguae*).

All central collection and treatment alternatives will result in very high user charges and will be difficult for the City of Willard to finance, even with grant assistance. An archaeological survey of the force main route to the Springfield northern system and previously recorded information did not reveal any cultural resources that would be affected by the proposed project (164).

I. UNINCORPORATED LOW GROWTH SUBAREA

The Draft Facilities Plan presents sound technical guidelines for on-site system design, construction, and operation. Emphasis should also be placed on flow reduction and other means to modify wastewater characteristics. Adoption and implementation of an on-site system management plan will be needed for effective application and enforcement of technical policies. The goals of the plan include sound design and construction practices; periodic inspections; periodic removal and proper disposal of septic tank solids; maintenance of pumps, dosing siphons, and other equipment; and wastewater characteristics modification.

Varying approaches and many detailed items need to be addressed in implementing an on-site system management plan. Planning and zoning regulations and building codes are important tools and are being used to a limited degree in Greene County. Licensing of system installers plus inspections during installation are useful approaches. Programs to reinspect, maintain, and upgrade existing systems are needed, but are often controversial, difficult, and expensive to implement.

VI. RECOMMENDATIONS AND PROPOSED ACTION

This section discusses recommendations for mitigating significant impacts and EPA's proposed action.

A. SUGGESTED MITIGATION OF SIGNIFICANT IMPACTS

The specific alternatives for each subarea and significant environmental impacts were discussed in Section V. This section further discusses and summarizes recommended mitigation measures which could reduce or eliminate the significant adverse effects of the proposed alternatives.

The change in the proposed Strafford project from that proposed in the Draft Facilities Plan will significantly reduce potential environmental impacts. Pumping to the Springfield southern system, as currently proposed, will avoid discharge to the South Fork of the Pomme de Terre River. This stream and the Pomme de Terre River further downstream are attractive small streams which do not now receive any major wastewater discharges. Chlorination to protect recreational use and dechlorination to protect aquatic life, including the Niangua darter, would be required for discharge to the South Fork of the Pomme de Terre River. The Niangua darter is listed as "rare" by the Missouri Department of Conservation and under study by the U.S. Fish and Wildlife Service for listing as "threatened." Impacts would be relatively minor from properly treated effluent; however, the potential impact in the event of serious treatment system upsets, inadequate dechlorination, or the overflow and bypassing of raw sewage would be severe. There are no significant adverse environmental impacts associated with the proposed pump station and force main to the Springfield southern system. An archaeological survey of the route has not been conducted, however.

Depending upon losing stream determinations for the Walnut Grove discharge alternatives, chlorination and dechlorination to protect aquatic life may be needed. The alternatives of discharging to Sugar Creek, Turkey Creek, or a tributary of Turkey Creek are still being evaluated.

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The proposed force main from Willard to the Springfield northern system should be designed to minimize potential problems from sinkhole subsidence. A geotechnical survey should be required during final design stage to identify the sinkhole areas, assess the subsidence potential, and recommend specific measures for mitigation. The use of ductile iron force main, as proposed, and pipe joints that provide flexibility without leakage are recommended. Flow and pressure monitoring and alarm systems should be provided as warranted.

The proposed South Dry Sac, Little Sac River, and Pierson Creek interceptors, and the proposed Battlefield and Fair Grove facilities will have potentially significant impacts on prehistoric archaeological sites. The sites have been identified as potentially eligible for inclusion in the National Register of Historic Places. During the detailed design stage, the proposed facilities should be modified to avoid these sites, or, if avoidance is not possible, test excavations should be conducted to determine their significance. Mitigation of archaeological impacts should be coordinated with the Center for Archaeological Research, Southwest Missouri State University.

Sedimentation and erosion control measures are particularly important during construction of the proposed Pierson Creek, South Dry Sac, and Little Sac River interceptors. These interceptors involve long lengths of streamside construction, numerous stream crossings, and potential reservoir or stream siltation. The Pierson Creek interceptor is above Springfield's James River water supply intake and Lake Springfield. Strict stream crossing and sediment control specifications for construction of these facilities (and the preservation of a "green belt" along the waterways) should be prepared during the final design stage and followed during construction.

Several interceptors will have significant impacts on bottomland forests, a valuable wildlife habitat. Aligning interceptors and minimizing the width of construction corridors through these areas to reduce these impacts is recommended.

Despite efforts to plan the most cost-effective projects, costs to residents in the unsewered communities will be very high. There is little more that can be done at this stage. Means of further reducing costs and obtaining additional financial aid should be pursued if opportunities arise.

B. EPA's PROPOSED ACTION

The U.S. Environmental Protection Agency has been involved with the development of the Greene County Facilities Plan since the original planning efforts began in 1979. Throughout that time, the Environmental Review Branch of EPA Region VII has coordinated closely with the Greene County Sewer District, county and municipal officials, the Missouri Department of Natural Resources and the Facilities Plan consultants in evaluating the environmental effects of the wastewater management alternatives considered. The results of that environmental analysis have been presented in this EIS.

Based on that analysis, and pending review comments on this Draft EIS by the citizenry of the planning area, and by concerned city, county, state, and federal departments and agencies, EPA proposes to pursue the following course of action:

- EPA has found no significant environmental basis to oppose further federal grants for the design and construction of the various alternatives proposed in the Draft Facilities Plan as updated in this Draft EIS. Federal funding for these projects will still be subject to all other review and approval requirements of EPA's Construction Grants Program, as well as to the requirements of the Missouri Department of Natural Resources. Recommended mitigative measures as discussed in Section VI-A should be implemented during final design and construction.

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APPENDIX A - GEOLOGY AND SOILS BACKGROUND INFORMATION

Section 1. Stratigraphic Description of Outcropping Formations

Following are brief stratigraphic descriptions of the formations, beginning with the oldest (lowest), that outcrop at some point in the planning area (see Figures 3 and 4):

a. Ordovician System - Canadian Series. The lowest aquifer (water-bearing formation) with major outcropping in the Springfield vicinity is the Cotter Dolomite, a brown-to-buff dolomite with layers of chert and sandstone. (Dolomite is a carbonate sedimentary rock with a relatively high magnesium content.) A sandstone designated locally as the "Swan Creek" occurs in the lower part of the formation. It is about 15 to 20 feet thick, is prevalent in this area, and outcrops in Northview, Webster County, just to the east of the planning area. [A small area of Roubidoux sandstone, also an aquifer of older Ordovician age and thrust up by the Fair Grove fault, outcrops in the extreme northeast corner of Greene County (12)].

b. Mississippian System - Kinderhookian Series.

1) Bachelor Formation - a thin formation about 2 to 6 inches thick, consisting of two greenish sandstones, the upper one calcareous. This formation marks the base of the Mississippian System.

2) Compton Formation - usually a light gray, fossiliferous limestone, 10 to 15 feet thick, which is sometimes dolomitized in northern Greene County. Crinoid fossil remains consisting of thin disks of calcite impart a peppery appearance to this formation. (Crinoids are a group of marine invertebrates.)

3) Northview Formation - a silty formation varying in thickness from about 5 feet in the southern part of Greene County to about about 80 feet in the northern part of the county. In the north, the lower part is a dolomitic siltstone and shale, and the upper part is a silty dolomite. The southern part of the formation is a greenish-gray silty shale. The Northview acts as a confining layer, separating the upper and lower aquifers of the region. (The commonly referred to "upper" and "lower" aquifers are actually each composed of several water-bearing formations.) It is exposed along the North Dry Sac River, the Little Sac River, and the Eureka Springs Escarpment.

c. Mississippian System - Osagean Series.

1) Pierson Formation - a silty dolomite grading upward into a dolomitic cherty limestone. The "type section," or representative stratum by which the formation is defined, named after Pierson Creek, averages about 40 feet in thickness and thins to the north while becoming less dolomitic. Southward from Springfield, the Pierson becomes a fossiliferous limestone and the upper part increases in chert content.

2) Elsey Formation - a gray crinoidal limestone interbedded with up to 50 percent nodular chert. The formation averages about 50 to 60 feet in thickness in Greene County. It is transitional to the formations above and below, so its exact thickness is difficult to determine.

3) Burlington and Keokuk Limestones (undivided) - a light gray crinoidal limestone grading from coarsely crystalline at the base to finely crystalline at the top and interbedded with nodular chert zones at intervals of 15 to 20 feet. The Short Creek oolite member, about 4 to 6 feet thick, marks the top of the Keokuk Limestone and of the Osagean Series. (An oolite is a rock consisting of tiny accretionary grains.)

d. Mississippian System - Meramecian Series. The only member outcropping near Springfield is the Warsaw Formation, a light gray crystalline limestone marking the bottom few feet of the series.

e. Pennsylvanian System, Warner Formation. Scattered outcrops of conglomerate (cemented gravel) and sandstone represent the Pennsylvanian System in Greene County. They are located mainly in the western part of the county, although this formation also caps Fair Grove Mound in the northeastern part. These outcrops are believed to be remnants of channel deposits of streams that cut down into the Mississippian formations. These are local deposits, although in the literature they are generally mapped as regions (12).

f. Pleistocene Series

Some polished gravels in the planning area are believed to represent Pleistocene terrace deposits. The alluvium of streams in the area are probably Pleistocene and recent in age.

Section 2. Unusual Geologic Features

A number of unusual geologic features are located in the planning area (see Figure 6). The most noteworthy of these are listed in a Missouri Division of Geology and Land Survey publication (23) and are as follows:

a. Blue Spring Natural Tunnel - in Christian County, southeast of Battlefield. Flow into the tunnel, which is an elongated, northeast-trending sink, emerges at Blue Spring, 0.3 mile northwest of the tunnel entrance.

b. Ash Grove Natural Tunnel - near Ash Grove. The tunnel is a remnant of a partially collapsed cave system. Effluent from the old Ash Grove sewage plant was discharged into the tunnel until 1973 when a new sewage plant became operational. The entire flow of Dry Fork Creek runs through the tunnel for 1000 feet before discharging into the Sac River.

c. Cave Spring Natural Bridge - on the west side of Highway AC near the village of Cave Springs. This is not a true natural bridge, but a breached, water-filled cave system.

d. Crighton Natural Bridge - on Natural Bridge Farm east of U.S. 65, north of Battlefield Road; a case of stream capture and diversion in the present valley beneath the bridge. The downstream end is a hanging valley discharging into a steep-walled gorge. About 100 feet north, a spring flows from a cave in the gorge wall.

e. Dry Sac Lost Hill Area - on South Dry Sac Creek between the Springfield city limit and McDaniel Lake, east of Highway 13. The area contains an abandoned, entrenched meander loop; a lost hill; two natural arches; a tight-crawl natural tunnel; several caves; and pinnacled limestone with a low waterfall.

f. Fair Grove Mound - on the east side of Highway 65, south of Fair Grove. The mound is a Mississippian limestone erosional remnant, about 200 feet, capped with Pennsylvanian conglomerate.

g. Mill Street Natural Bridge and Cave - east of U.S. 65, north of Cherry Street.

h. Stonebridge (Mobley Natural Bridge and Springs) - near the Sac River, southwest of Bois d'Arc. The bridge is a roof remnant of a collapsed cavern, with alternating layers of chert and limestone of the Elsey Formation. The bridge, cave, and spring have been developed as a private park.

i. Shaking Mound Spring - on the Sac River, near Stonebridge. The mound is a peat bog in the river bottom near the junction of Pickerel Creek and the Sac River.

j. Valley Water Mills Fault Block - extending eastward from the reservoir, just north of the Springfield city limit, east of Highway 13. About 500 feet wide by several miles long, this 130-foot uplift is flanked on both sides by faults, with broken rock in the fault zone. It is responsible for leakage along the west bank of Valley Water Mills reservoir.

k. Saunders Valley and Alvin Sink - in Christian County, southeast of Battlefield (not listed by the Division of Geology and Land Survey).

Section 3. Soils Series Descriptions

Descriptions of the soil series listed in Table A-1 are given below (3, 24, 25). Depths to bedrock exceed 5 feet unless indicated otherwise. Soils maps from the Draft Facilities Plan showing septic system limitations and prime farmland are also included.

Alluvial Land - formed on the floodplains and in narrow alluvial bottomlands from shale and cherty limestone.

Alsup Flaggy Silt and Silty Clay - a deep, moderately drained soil formed in a thin colluvium of loess over residuum weathered from shale on uplands. The soil is a flaggy (laminate) silt over flaggy silty clay. Depth to bedrock exceeds 1 meter (3.3 feet). Permeability is moderately slow.

Bado Silt and Silty Clay - a deep, poorly drained soil formed in loess over residuum weathered from cherty limestone, with fragipans on upland ridges. The soil profile is a silt over two fragipan layers that are separated by silty clay. Cherty silty clay extends below the fragipan. The soil is very slowly permeable, has a high shrink-swell potential, and has a seasonal perched water table above the fragipan.

TABLE A-1
SOIL CHARACTERISTICS AND LIMITATIONS FOR SEWAGE TREATMENT FACILITIES

Soil Series	Map Symbol Symbol	Percent Slope	Septic Systems (1)	Lagoon (1)	Shallow Excav. (1)	Area Landfill (1)	Corrosion Steel/Concr. (2)	Hydraulic Group (3)	Prime Farmland
Newtonia	1B	1-3	B,1	B,2,5	C,8	A	M/M	B	X
Pembroke	2B	1-5	A	B,5	B,8	A	L/M	B	X
Eldon	3D	5-14	B,1,5	C,5	B,5,8	B,5	M/M	B	
Wilderness	5C	2-9	C,3,1	C,3	C,3	C,3	L/H	C	
Creldon	6B	1-4	C,3,1	C,3	C,3	B,3	H/H	C	X
Needleye	9B	1-3	C,1,3	B,5	C,3	B,3	M/H	C	X
Bado	10	-	C,3,1	A	C,3	C,3	H/H	D	X
Sampsel	11B	2-5	C,3,1	B,5	C,3	B,6,3	H/L	D	X
Barco	16B	2-5	C,6	C,2,6	B,6	C,6,2	L/M	B	X
Peridge	21B	2-5	B,1	B,2,5	B,8	A	M/M	B	X
Bolivar	23B	2-5	C,6	C,6	B,6	C,6	L/M	B	X
Collinsville	26D	2-14	C,6	C,6,5	C,6	C,6	L/M	C	
Basehor	27D	2-14	C,6	C,2,6,5	C,6	C,6,2	L/M	D	
Keeno	30C	2-9	C,3,1	C,2,3	B,7,8	C,2	M/H	C	
Freeburg/	32C	2-9	C,3,4,1	C,4,3	C,3	B,4,3	M/H	C	
Alsup			C,3,1	C3	B,3,8	B,6,3	H/M	C	
Keeno/	33B	2-5	C,3,1	C,2,3	B,7,8	C,2	M/H	C	
Eldon			B,1	B,2,5	B,8	A	M/M	B	
Clarksville	35D	5-14	B,5	C,2,5	B,5,8	C,2	L/H	B	
Nixa			C,1	C,5	B,5	M/M	C		
Goss	43D	5-14	B,1,5,7	C,2,5	B,5,7,8	C,2	M/M	B	
Goss/	44E	2-50	C,5	C,2,5	C,5	C,2,5	M/M	B	
Gasconade			C,6,5,7	C,5,6,7	C,5,6,7	C,6,5	L/H	B	
Nixa	50C	2-9	C,1	C,5	B,5	B,5	M/M	C	
Wilderness/	53B	2-5	C,3,1	C,3	C,3	C,3	L/H	C	
Goss			B,17	C,2	B,7,8	C,2	M/M	B	
Lanton	54	-	C,4,3,1	C,4,3	C,3	C,4,3	H/L	D	X
Huntington	55	-	C,4	C,4	C,4	C,4	L/M	B	X
Osage	56	-	C,4,3,1	C,4,3	C,3	C,4,3	H/M	D	X
Hoberg	61B		C,3,1	B,5	C,3	B,3	M/H	C	X
Hepler	76	-	C,4,3,1	C,4,3	C,3	C,4,3	H/M	B/D	X
Viraton	81B	2-5	C,1,3	C,3	C,3	B,3	M/H	C	X

TABLE A-1 (Continued)
SOIL CHARACTERISTICS AND LIMITATIONS
FOR
SEWAGE TREATMENT FACILITIES

Soil Series	Map Symbol Symbol	Percent Slope	Septic Systems	Lagoon	Shallow Excav.	Area Landfill	Corrosion Steel/Concr.	Hydraulic Group	Prime Farmland
Gasconade/ Rock	83D	2-20	C,6,7	C,6,7	C,6,7	C,6	H/C	D	
Cedargap	94,95	-	C,4	C,2,4	B,4	C,4,2	L/L	B	X
Gerald	240	-	C,3,1	A	C,3	C,3	H/H	D	X
Parsons/	241B	1-3	C,3,1	A	C,3	C,3	H/M	D	X
Sampsel					C,3	B,6,3	H/L		
Secesh/	921	-	C,4	C,2,4	B,4	C,4,2	L/M	B	X
Cedargap					B,4	C,4,2	L/L		
Waben	931	0-5	A	C,2	A	C,2	L/M	B	
Cedargap			C,4	C,2,4	B,4	C,4,2	L/L		

Notes

1) Degree and kind of soil limitations affecting septic tank absorption fields and sewage lagoons.

A = slight if soil properties and site features are generally favorable for the indicated use and limitations are minor and easily overcome

B = moderate if soil properties or site features are not favorable for the indicated use an special planning, design, or maintenance is needed to overcome or minimize the limitations

C = severe if soil properties or site features are so unfavorable or so difficult to overcome that special design, significant increases in Construction Costs, and possibly increased maintenance are required.

1. Percs slowly - slow movement of water through soil adversely affecting specified use
2. Seepage - movement of water through soil adversely affecting specified use
3. Wetness - water table new surface, slow drying
4. Floods - temporary inundation caused by overflowing streams or runoff from adjacent slopes
5. Slope - inclination of land surface adversely affecting specified use.
6. Depth to rock - bedrock less than five feet below surface.
7. Large stones - interference with installation

TABLE A-1 (Continued)
SOIL CHARACTERISTICS AND LIMITATIONS FOR SEWAGE TREATMENT FACILITIES

2) Risk of Corrosion Rating - Low (L), Medium (M), High (H)

Uncoated Steel	Concrete
based on soil drainage class, total acidity, electrical resistivity new field capacity electrical conductivity of the saturation extract	based on soil texture acidity, amount of sulfates in the saturation extract

3) Hydrologic Group Rating

A	High rate of infiltration and transmission; low runoff,
B	Moderate rate of infiltration and tramission
C	Slow rate of infiltration and transmission
D	Very slow rate of infiltration and transmission; high runoff

Barco Loam - a moderately deep, well-drained upland soil formed in residuum weathered from acid sandstone. The soil is sandy loam above sandy clay over soft sandstone. Depth to bedrock ranges from 0.75 to 1 meter (about 2.5 to 3.5 feet). Shallow bedrock and moderate shrink-swell characteristics are construction limitations of this soil.

Basehor Loam - a shallow, well-drained soil formed in material weathered from sandstone. Permeabilty of the soil is moderately rapid. The loamy soil grades into soft and hard sandstone. Depth to bedrock is 25 to 50 cm (about 0.8 to 1.7 feet).

Bolivar Sandy Loam - a moderately well-drained upland soil formed in residuum weathered from acid sandstone. The profile consists of sandy to sandy-clay loams over sandstone. The soil is moderately permeable. Depth to sandstone bedrock is from 0.5 to 1 meter (about 1.7 to 3.3 feet). Hard sandstone is at depths from 1 to 1.75 meters (about 3.5 to 6 feet).

Cedargap Cherty Silt and Cherty Clay - a well- to somewhat excessively drained soil on floodplains of small streams, formed in cherty silty alluvium. The soil is either cherty silt, cherty silty clay, or cherty clay. Permeability is moderately rapid.

Clarksville Cherty Silty Clay - a deep, very cherty, somewhat excessively drained soil on steep slopes and narrow ridges. The soil is cherty silt over cherty to very cherty silty clay. Chert washes out of this soil down to the valleys during heavy rains. Pollution of groundwater may occur through fissures and sinks in the underlying limestone bedrock. Permeability is moderately rapid.

Collinsville Sandy Loam - a very shallow, well- to excessively drained soil, on upland sandstone, with moderately rapid permeability. The soil is fine sandy loam over hard sandstone. Depth to bedrock is from 10 to 50 cm (about 0.3 to 1.7 feet).

Creldon Silt and Silty Clay - a deep, moderately well-drained upland soil formed in loess over cherty residuum. The soil profile ranges downward from a silt through a silty clay to a very cherty silty clay fragipan to a very cherty clay. The soil dries slowly.

Eldon Cherty Silt and Clay - a deep, well-drained, very cherty soil formed on uplands from residuum weathered from limestone and interbedded shale and sandstone. The soil profile ranges from a cherty silt layer at the top through a very cherty silty clay to a clay. Permeability is moderate. Chert washes to the valleys in heavy rains.

Freeburg Silt and Clay - a deep, somewhat poorly drained soil formed in silty alluvium on stream benches. Permeability is moderately slow. The soil is a silt grading to a friable (easily crumbled) silty clay over a firm clay and a silty clay. It is subject to flooding and has a high shrink-swell potential.

Gasconade Flaggy Clay - a shallow, somewhat excessively drained soil on dissected landscapes and in isolated glade areas. The soil is a flaggy clay over limestone bedrock. Large stones are common in this soil. The soil has moderately slow permeabilty. Depth to bedrock is from 25 to 50 cm (about 0.8 to 1.7 feet).

Gerald Silt and Silty Clay - a deep, somewhat poorly drained upland soil formed in loess over cherty limestone residuum. The soil profile grades downward from a silt to a silty clay over clay. The fragipan is a silt over a cherty to very cherty silty clay. The soil is very slowly permeable.

Goss Stony Silt and Clay - a deep, well-drained stony soil formed on uplands in residuum from cherty limestone. The soil ranges from a stony silt to a cherty or very cherty silty clay. Chert is washed into the vallys during heavy rains. The soil is moderately permeable.

Goss Cherty Silt - a deep, well-drained cherty soil formed on uplands from residuum weathered from cherty limestone. The cherty silt becomes more clayey with depth. The soil contains large stones. Chert is washed to the valleys during heavy rains. The soil is moderately permeable.

Hepler Silt and Silty Clay - a deep, somewhat poorly drained soil formed in alluvium on low stream terraces. The soil is silt over silty clay. Permeability is moderately slow.

Hoberg Silt and Silty Clay - a deep, moderately well-drained soil formed in residuum weathered from cherty limestone with fragipans on upland and terrace ridges. The soil is either silt or silty clay over cherty clay.

Huntington Silt - a deep, well-drained soil formed in alluvial materials on flood plains. The soil is silt over a sandy clay and is subject to flooding. The soil is moderately permeable.

Keeno Cherty Silt and Clay - a deep, moderately drained soil formed in residuum weathered from cherty limestone, with fragipans on the uplands. The soil profile grades from a cherty silt, very cherty silt, and silty clay to a very cherty fragipan over a very cherty clay.

Lanton Silt and Clay - a poorly drained to somewhat poorly drained soil formed on floodplains. The soil is a silt grading to clay. Permeability is moderately slow. Soil is subject to frequent flooding.

Needleye Silt and Silty Clay - a deep, moderately well-drained soil formed in loess and cherty residuum with fragipans on uplands. The soil grades downward from a silt through a silty clay and very cherty silty clay to a cherty clay. The soil is slowly permeable and slow to dry.

Newtonia Silt and Silty Clay - a deep, well-drained soil formed on uplands. The soil is moderately permeable with silty clay in the lower portion and has severe shrink-swell characteristics.

Nixa Cherty Silt - a deep, very slowly permeable soil formed over weathered chert on ridge tops and sideslopes. The soil is a very cherty silt over a compact, brittle fragipan. Permeability is very slow.

Osage Silty Clay - a deep silty clay on low terraces and along streams. The soil is very slowly permeable and poorly drained, with severe shrink-swell characteristics.

Parsons Silt and Clay - a somewhat poorly drained, very slowly permeable upland soil with high shrink-swell potential. The soil ranges from dark silt to clay.

Pembroke Silt and Silty Clay - a deep, well-drained soil formed on uplands from loess and highly weathered limestone residuum. The silt surface layer is underlain by silty clay becoming cherty with depth and a firm silty clay overlying the bedrock. Bedrock is less than 3 meters (about 10 feet) below the surface.

Peridge Silt and Silty Clay - a deep, well-drained, moderately permeable soil. The shrink-swell potential is moderate. The soil ranges downward from a silt to a silty clay with a gravelly zone.

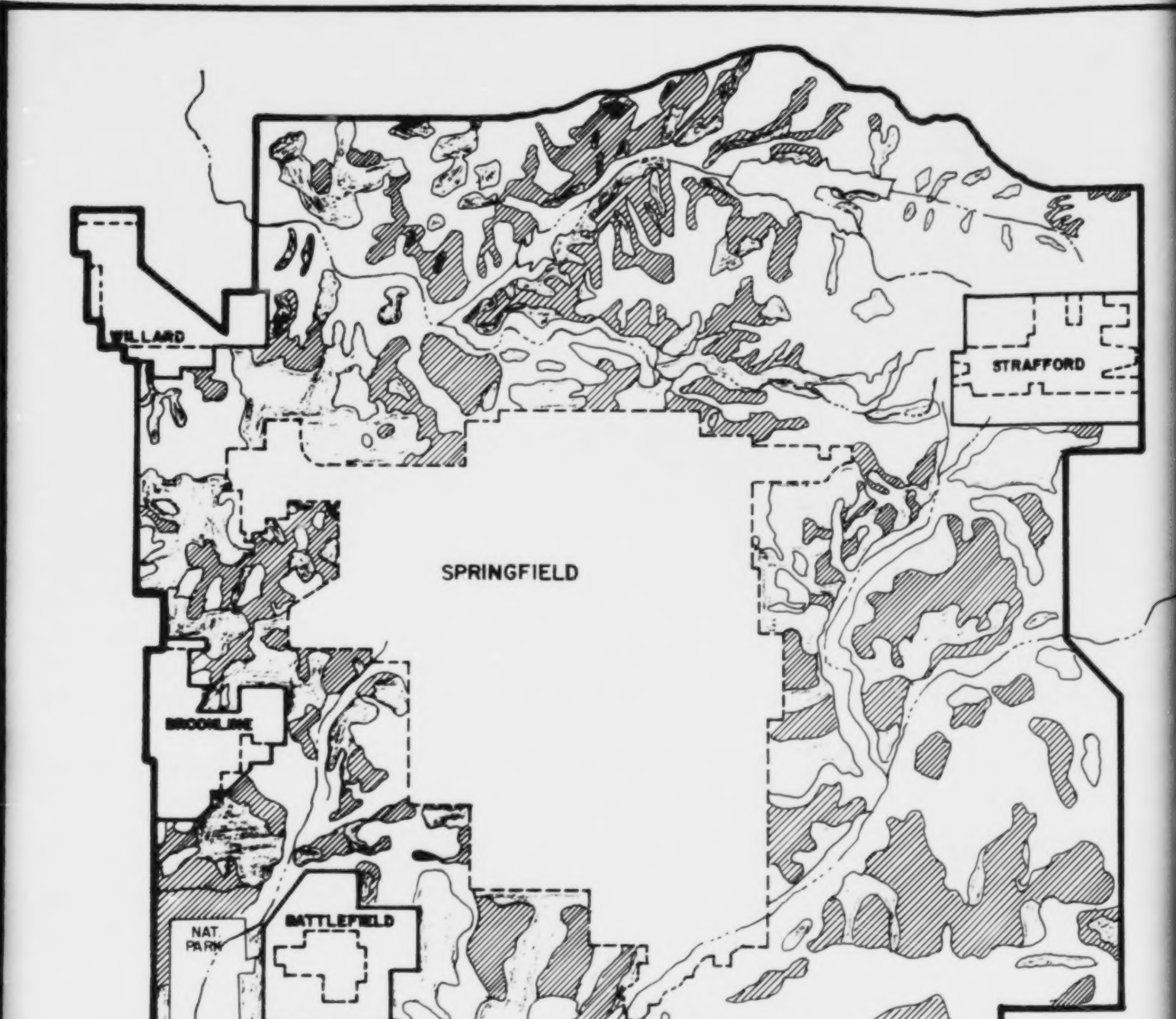
Sampsel Silty Clay - a deep, poorly drained soil formed in residuum weathered from shale on uplands. The soil is silty clay grading into a firm silty clay and clay. Depth to bedrock is from 1 to 1.75 meters (about 3.5 to 5.8 feet). The soil is slowly permeable and has severe shrink-swell characteristics.

Secesh Silt and Clay - a deep, well-drained soil formed on low stream terraces from cherty alluvium. The soil is loam to silty clay and cherty silty clay, grading into cherty and very cherty sandy clay. Permeability is moderate. Soil is subject to flooding.

Viraton Silt and Clay - a moderately drained soil formed over cherty residuum on uplands, foot slopes, and alluvial fans. The soil profile is a silt over a silty clay, an extremely cherty silt fragipan, and a clay. Soil is subject to seasonal wetness and slow permeability.

Waben Cherty Silt - a deep, well-drained soil of moderately rapid permeability, formed on narrow terraces, alluvial-colluvial fans, and ridge tops. The soil is cherty silt becoming very cherty silt at depth. The excessive permeability of this soil facilitates pollution of groundwater.

Wilderness Cherty Silt and Silty Clay - a deep, moderately drained cherty soil formed from residuum weathered from cherty limestone. This soil has fragipans which are slowly permeable on upland ridges. The soil profile ranges downward from a cherty silt to a very cherty silty clay through a fragipan layer of very cherty brittle silt overlying very cherty silty clay.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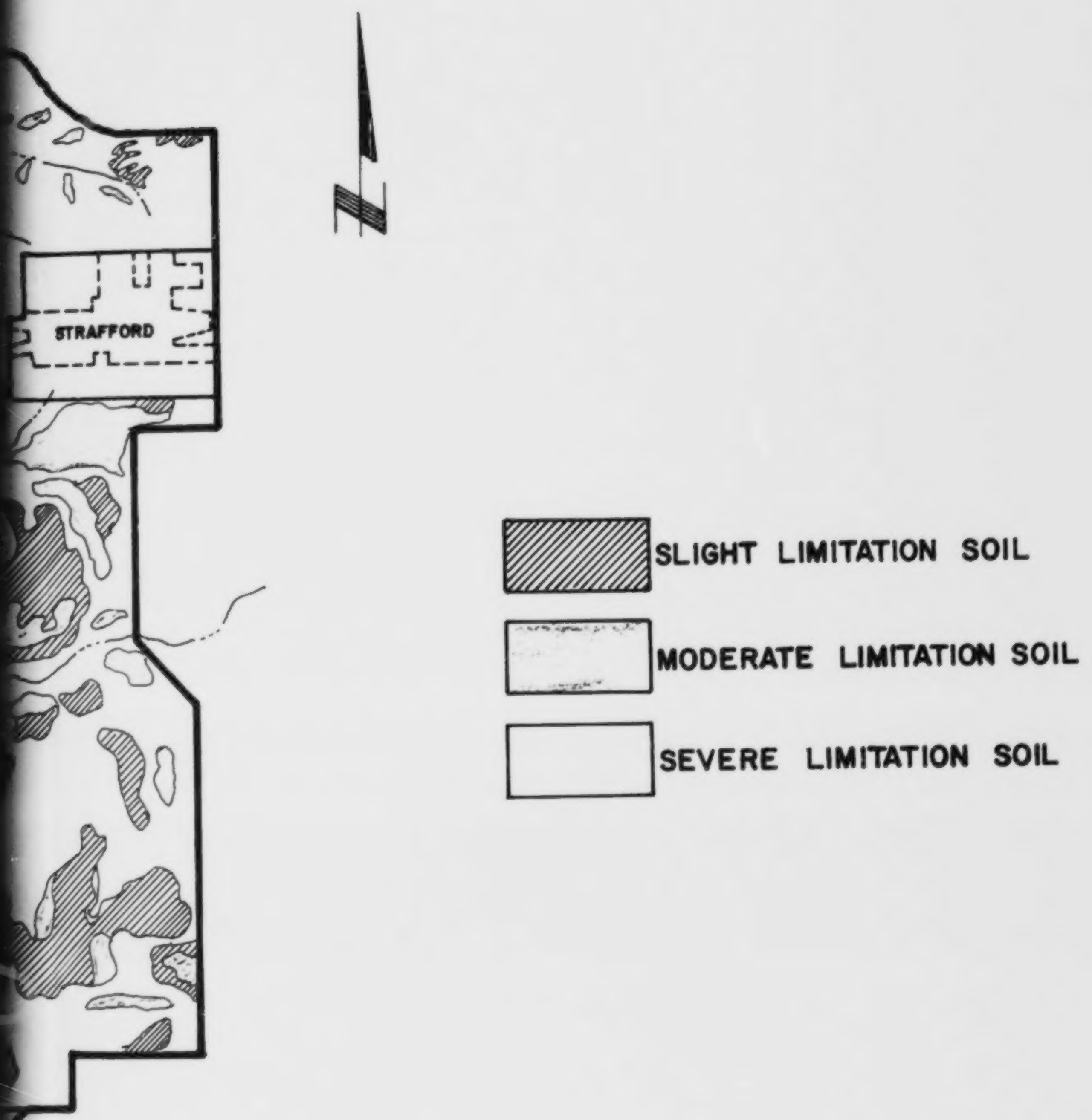
STRAFFORD
SPRINGFIELD
BROOKLINE
NAT. PARK
BATTLEFIELD
GREENE CO.
CHRISTIAN CO.



DEIS FIGURE A-1

GREENE COUNTY SEWER DISTRICT
SPRINGFIELD, MISSOURI SUBAREA
SUITABILITY FOR SOIL ABSORPTION FIELD
EXHIBIT # 2

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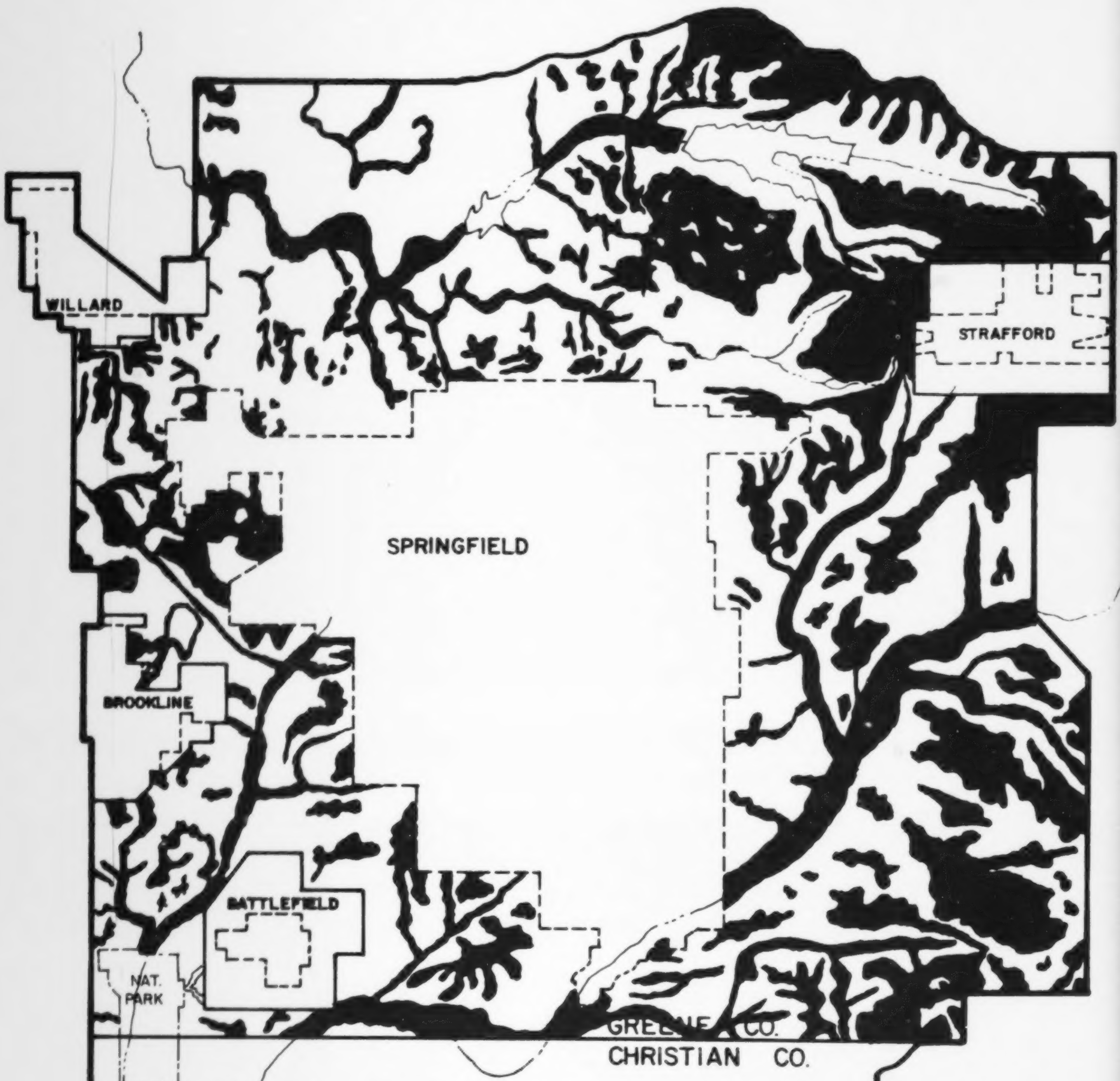
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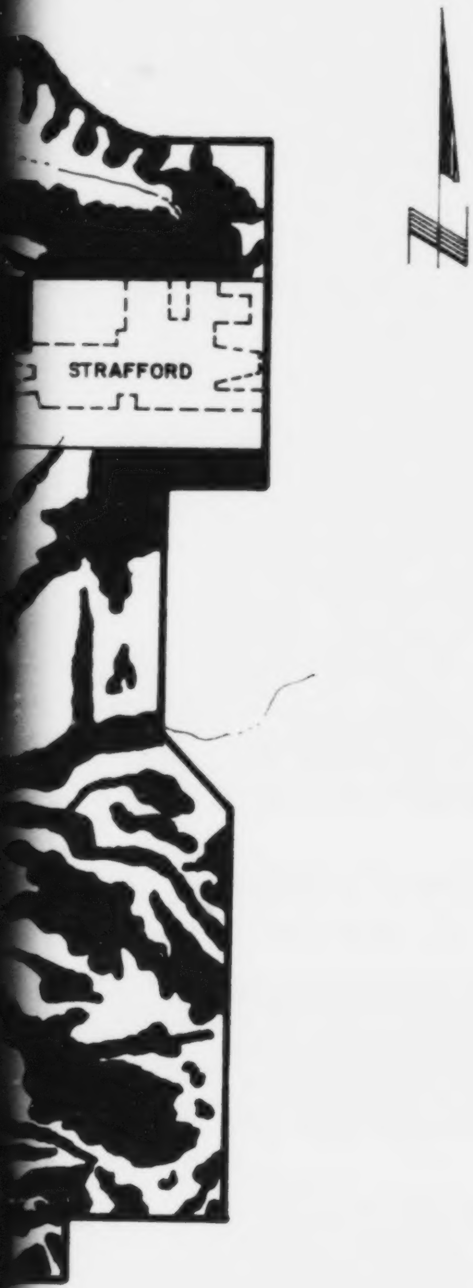
STRAFFORD
SPRINGFIELD
BROOKLINE
BATTLEFIELD
NAT. PARK
GREENE CO.
CHRISTIAN CO.
CHRISTIAN COUNTY SOIL INFORMATION NOT AVAILABLE



■ PRIME AGRICULTURAL LANDS

DEIS FIGURE A-2

GREENE COUNTY SEWER DISTRICT
SPRINGFIELD, MISSOURI SUBAREA
PRIME AGRICULTURAL LANDS
EXHIBIT # 3

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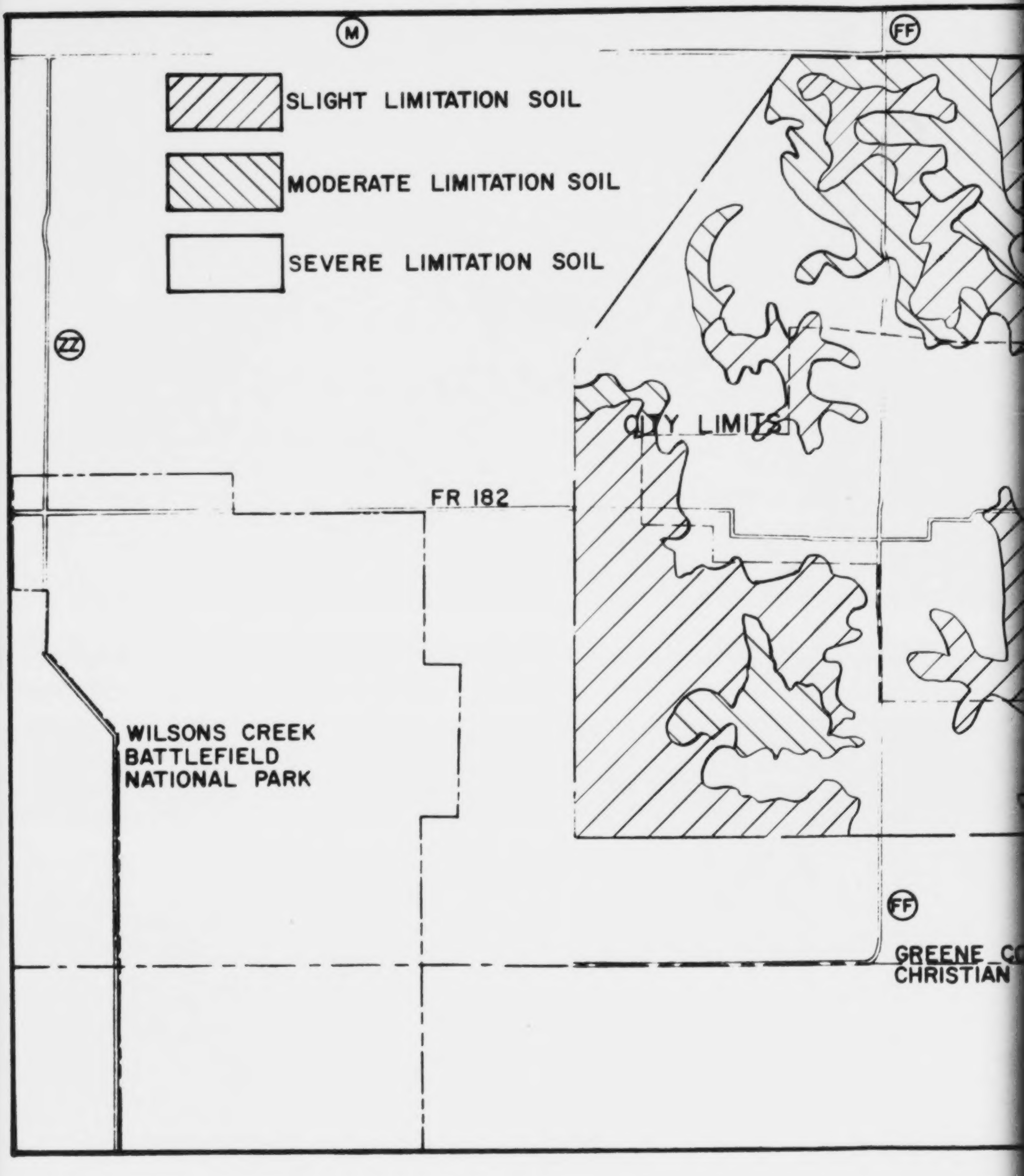
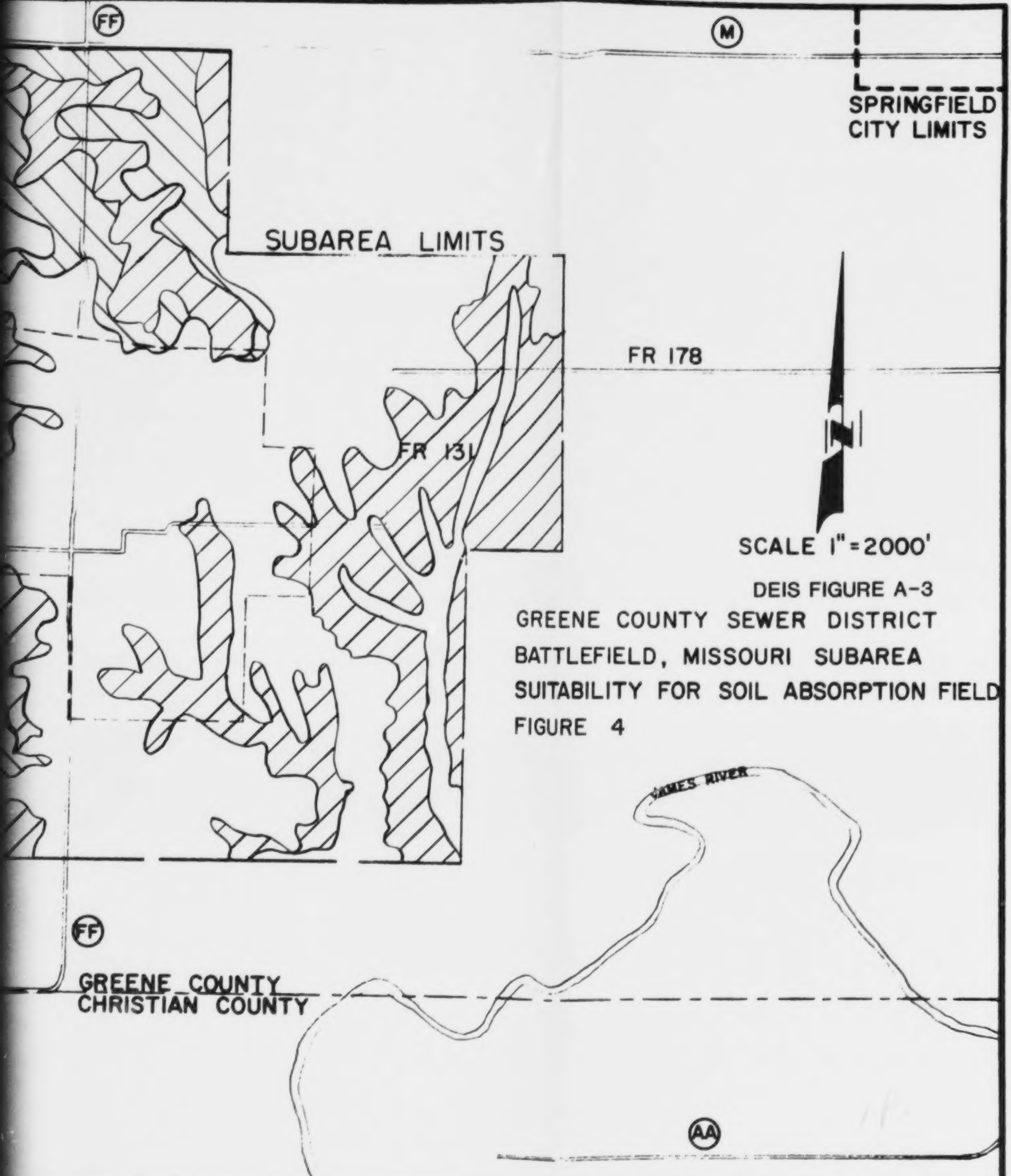

M
FF
SLIGHT LIMITATION SOIL
MODERATE LIMITATION SOIL
SEVERE LIMITATION SOIL
ZZ
CITY LIMITS
FR 182
WILSONS CREEK
BATTLEFIELD
NATIONAL PARK
FF
GREENE C
CHRISTIAN



SCALE 1" = 2000'

DEIS FIGURE A-3
GREENE COUNTY SEWER DISTRICT
BATTLEFIELD, MISSOURI SUBAREA
SUITABILITY FOR SOIL ABSORPTION FIELD
FIGURE 4

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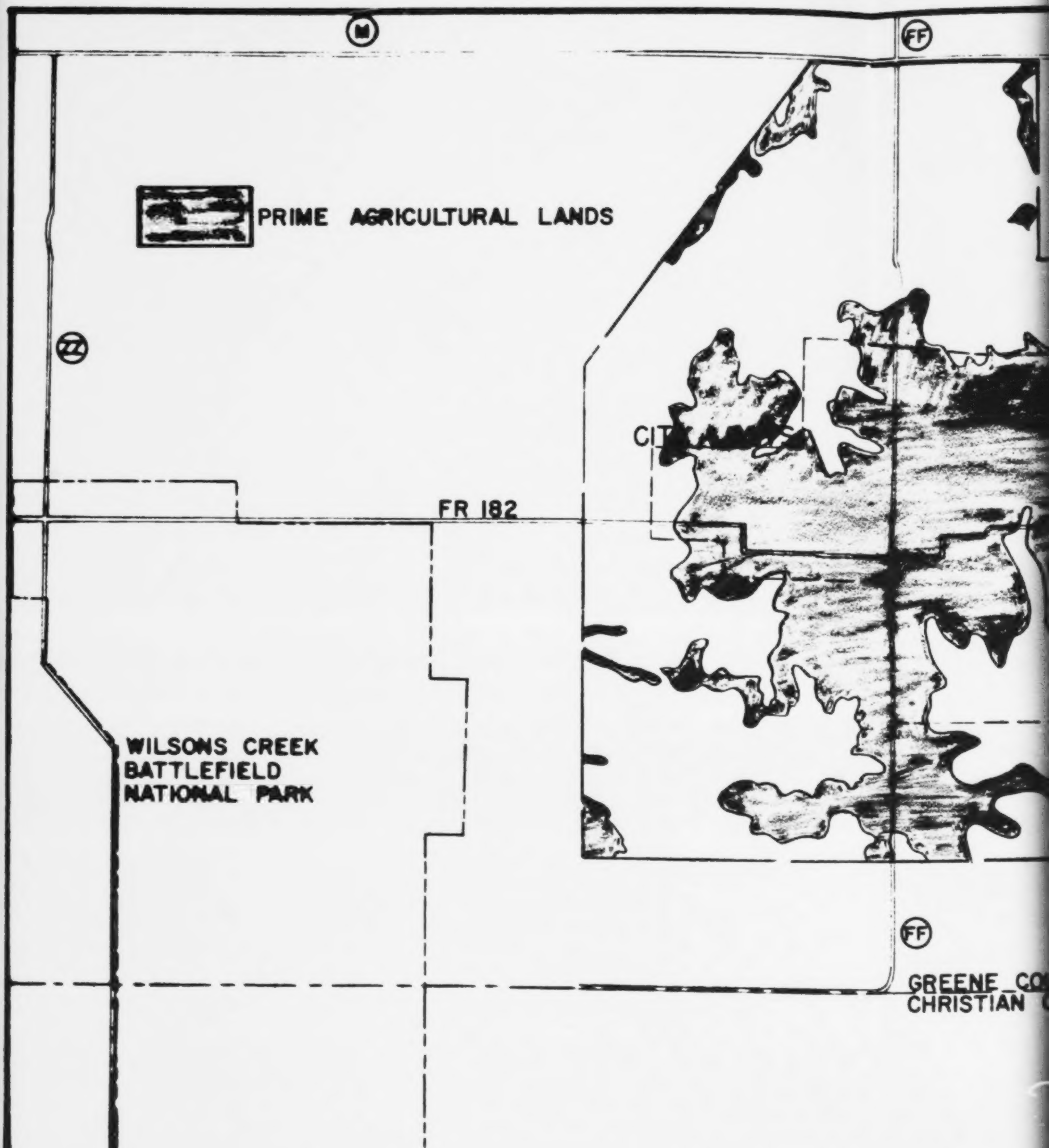
M
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PRIME AGRICULTURAL LANDS
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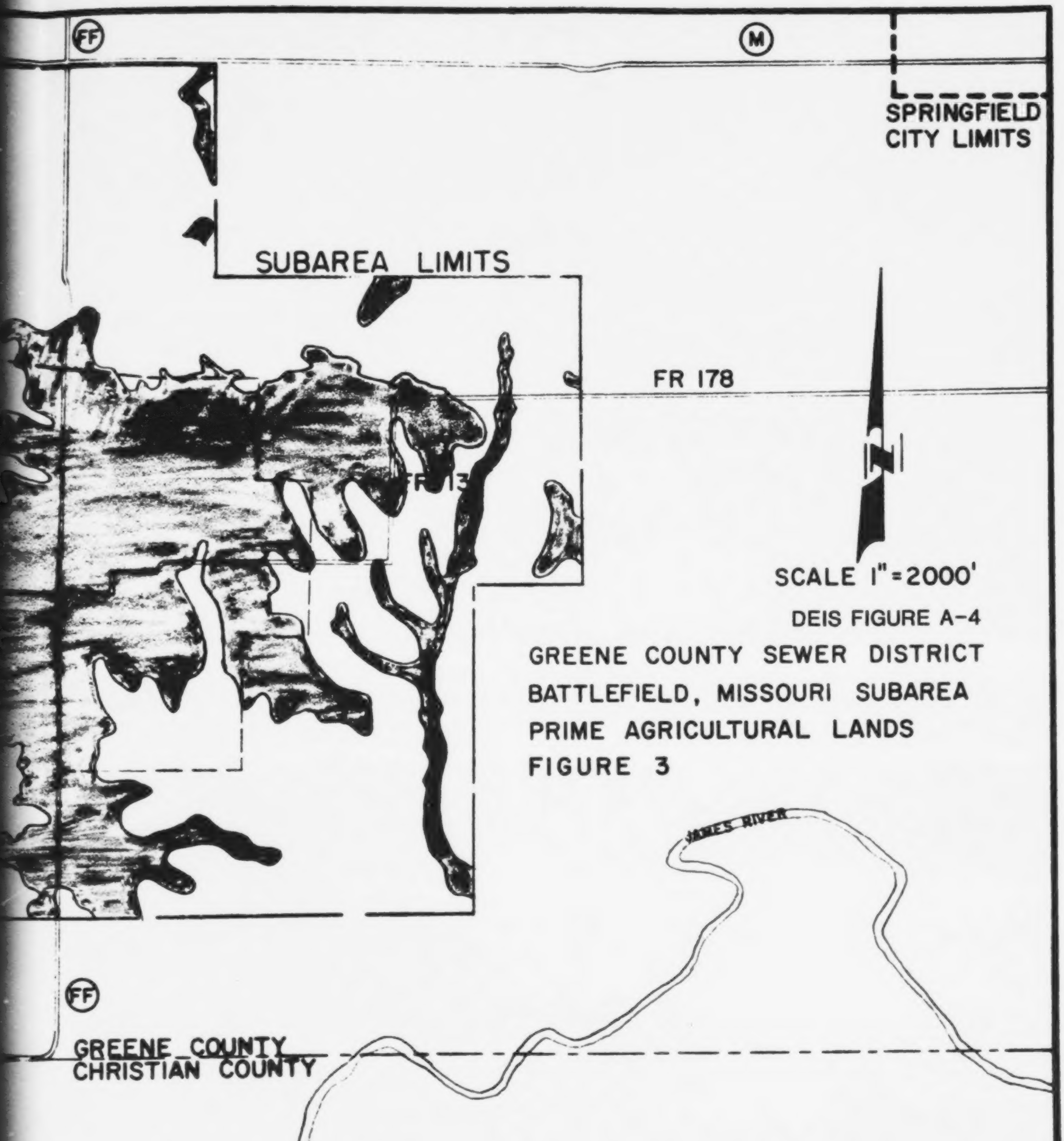
FR 182
WILSONS CREEK
BATTLEFIELD
NATIONAL PARK
FF
GREENE CO
CHRISTIAN C



DEIS FIGURE A-4

GREENE COUNTY SEWER DISTRICT
BATTLEFIELD, MISSOURI SUBAREA
PRIME AGRICULTURAL LANDS
FIGURE 3

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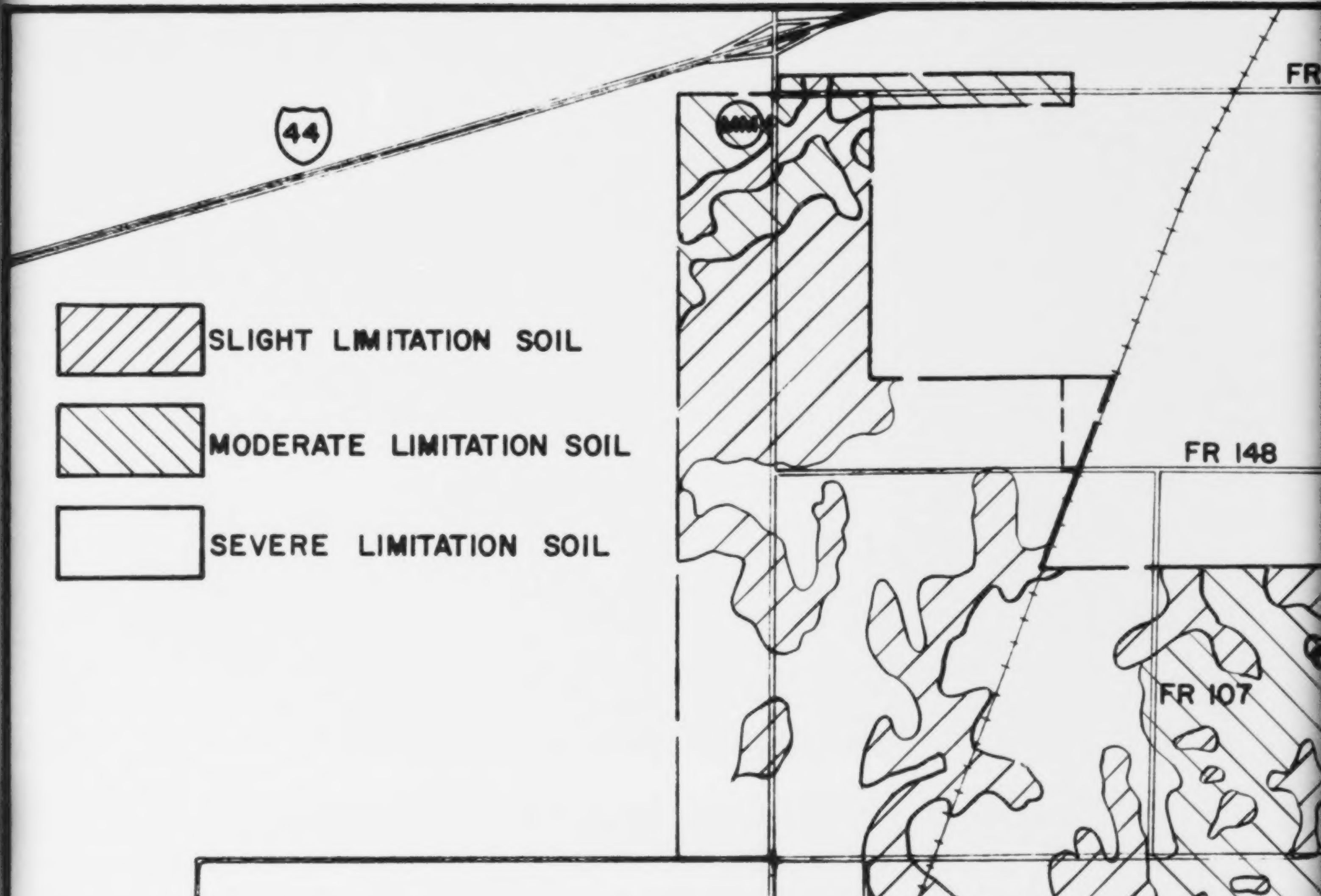
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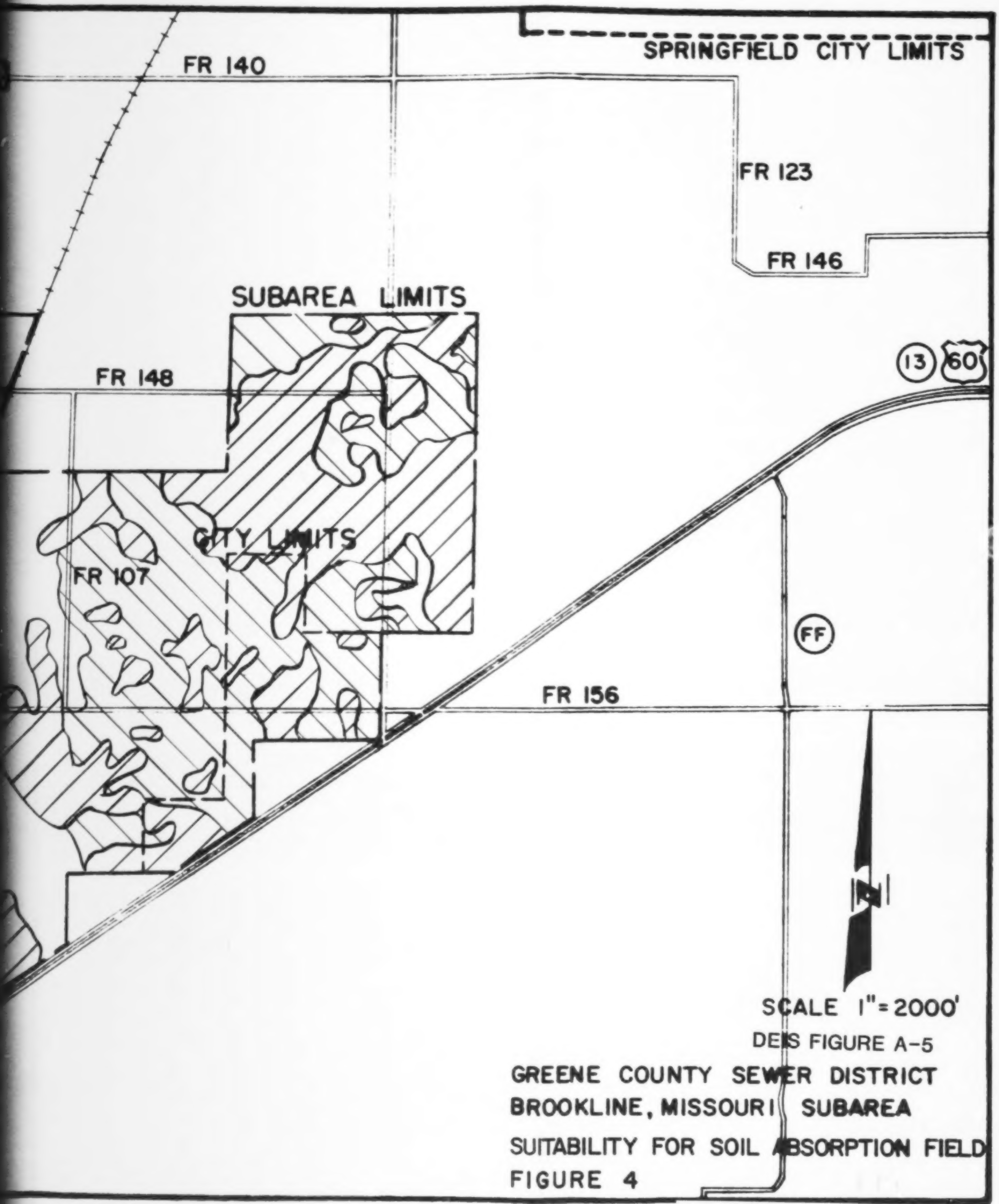
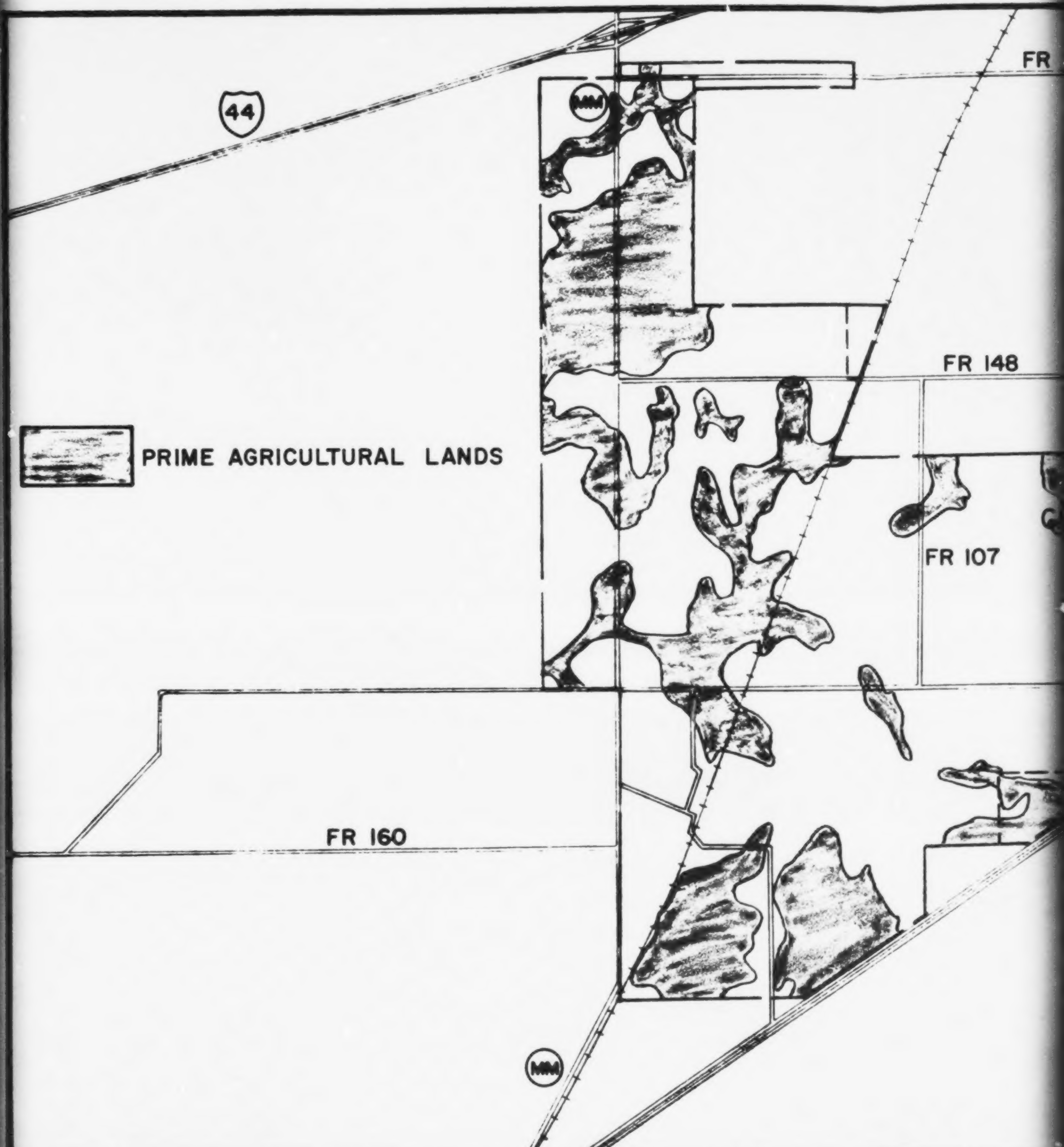
MODERATE LIMITATION SOIL
SEVERE LIMITATION SOIL
FR
FR 148
FR 107
FR 160



SCALE 1"=2000'

DEIS FIGURE A-5

GREENE COUNTY SEWER DISTRICT
BROOKLINE, MISSOURI SUBAREA
SUITABILITY FOR SOIL ABSORPTION FIELD
FIGURE 4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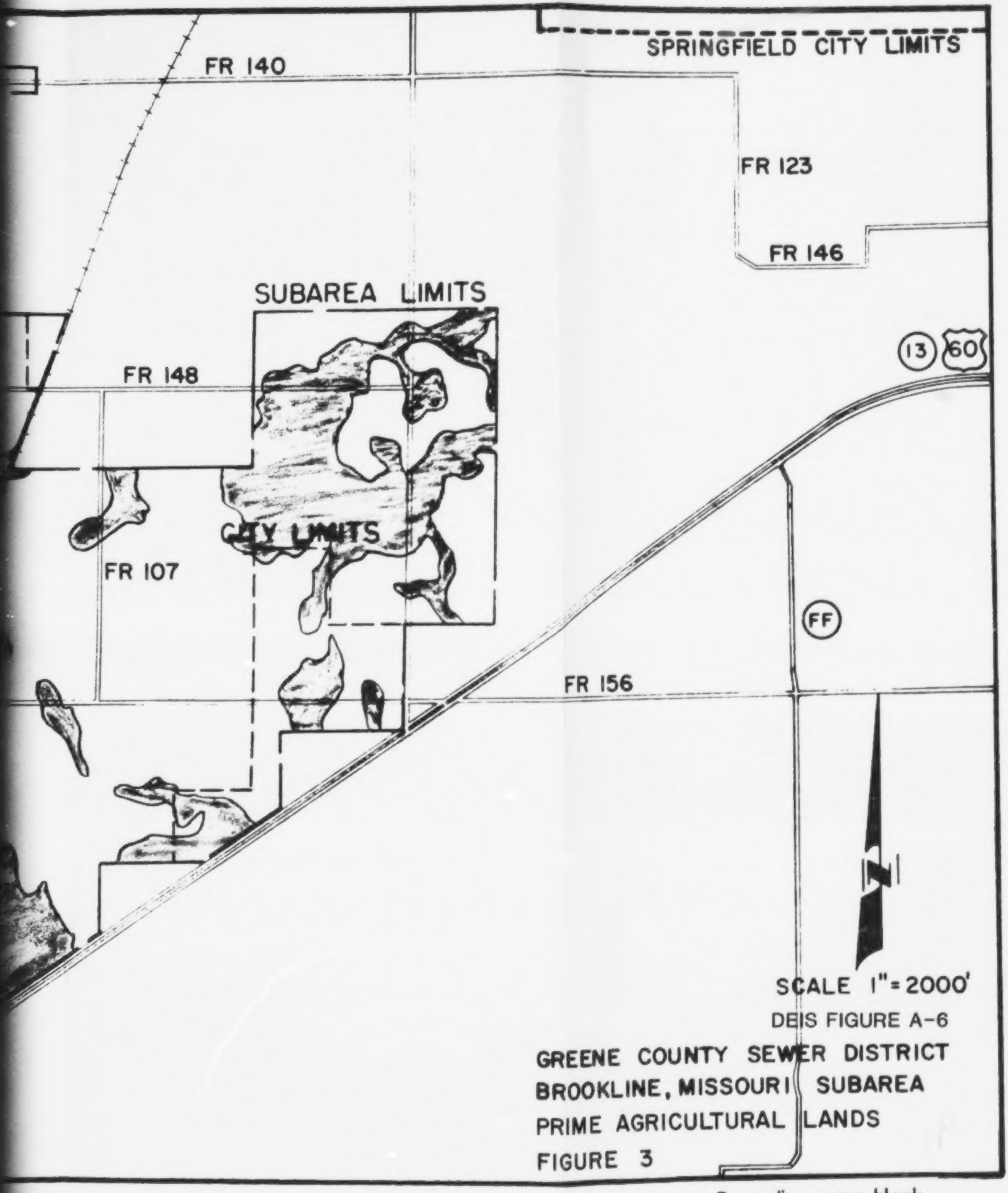
MM
FR
FR 148
PRIME AGRICULTURAL LANDS
FR 107
FR 160
MM



SCALE 1" = 2000'

DEIS FIGURE A-6

GREENE COUNTY SEWER DISTRICT
BROOKLINE, MISSOURI SUBAREA
PRIME AGRICULTURAL LANDS
FIGURE 3

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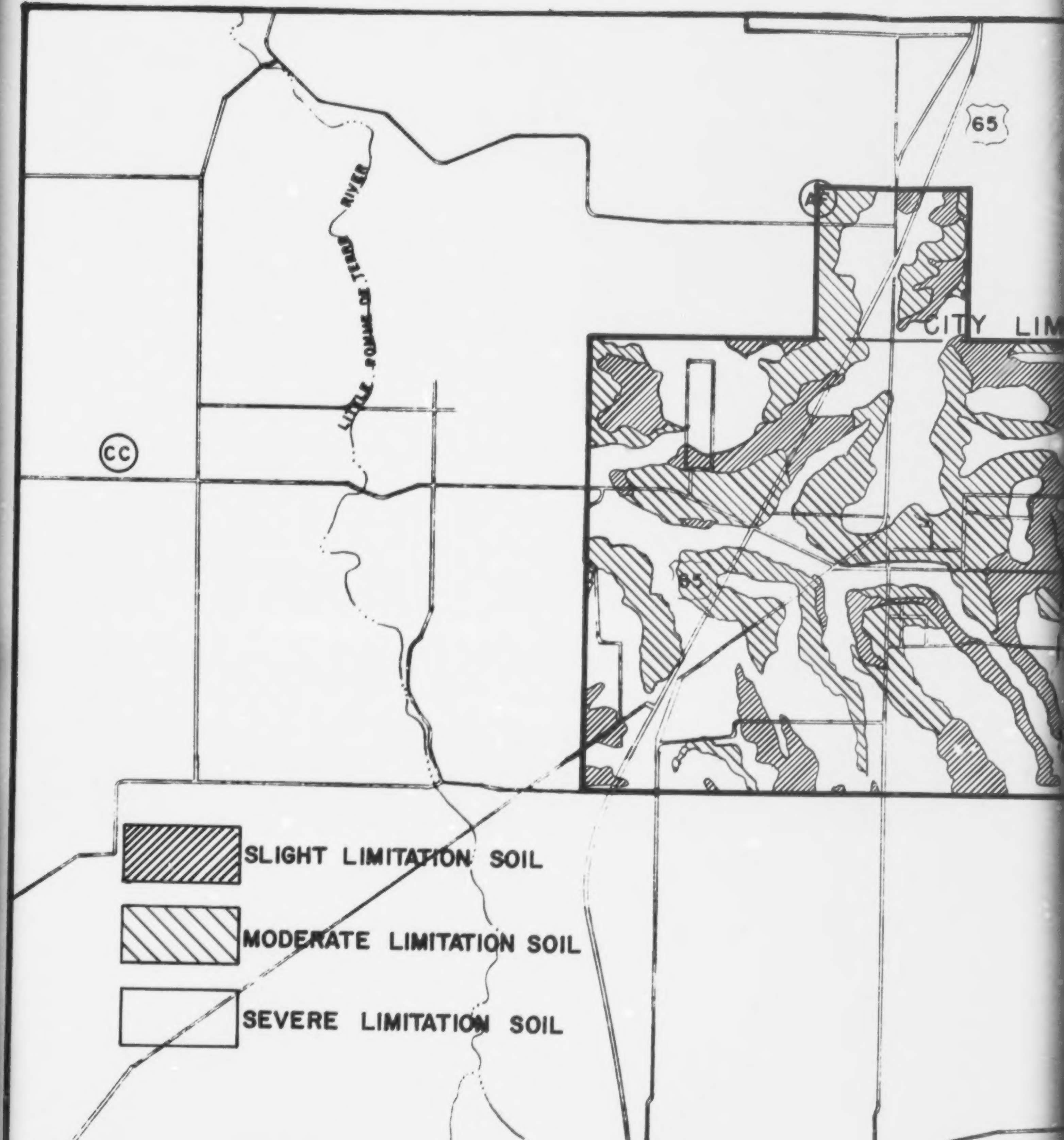
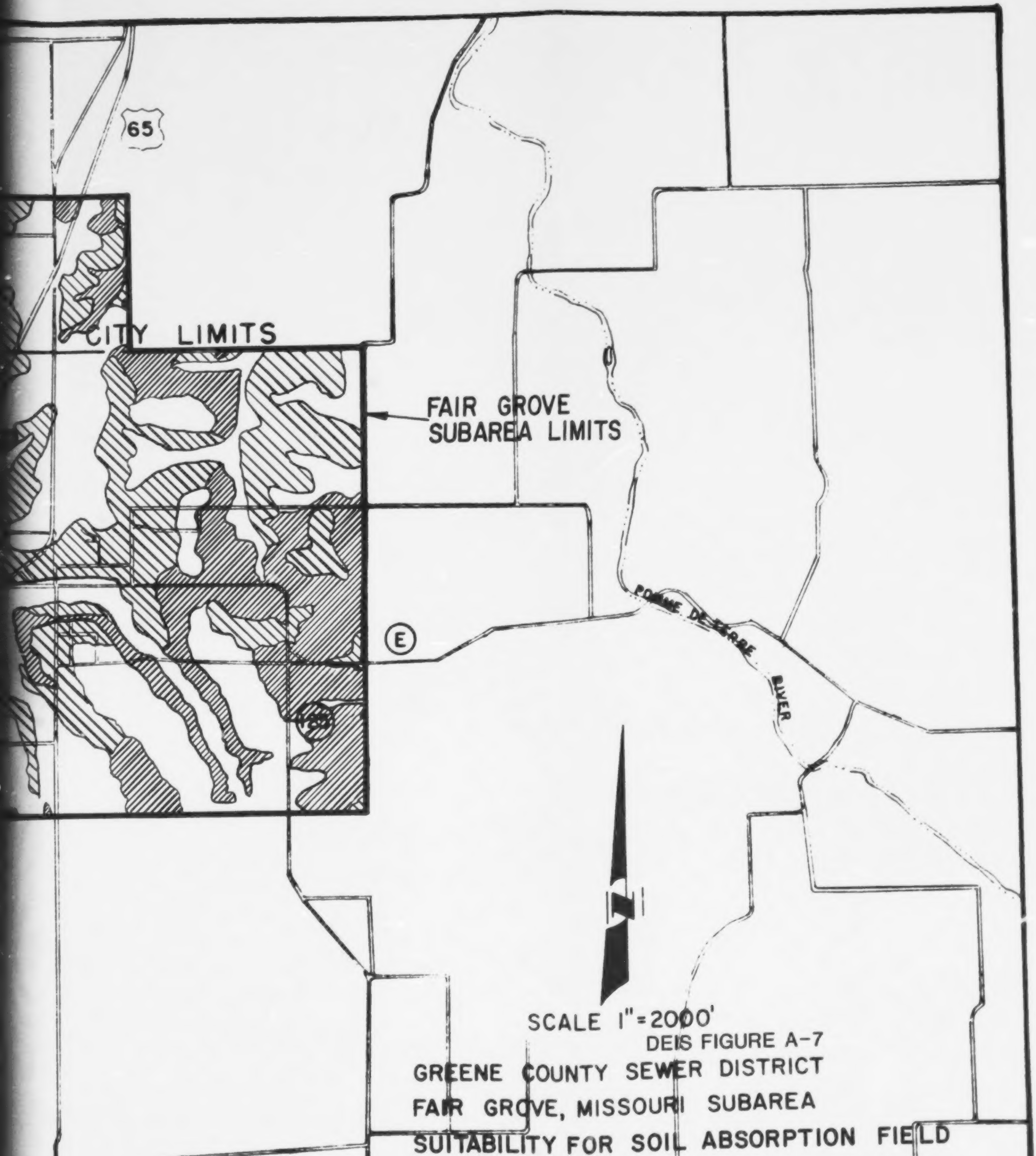

65
AF
CITY LIM
LITTLE POMME DE TERRE RIVER
CC
65
SLIGHT LIMITATION SOIL
MODERATE LIMITATION SOIL
SEVERE LIMITATION SOIL



DEIS FIGURE A-7

GREENE COUNTY SEWER DISTRICT
FAIR GROVE, MISSOURI SUBAREA
SUITABILITY FOR SOIL ABSORPTION FIELD
FIGURE 4

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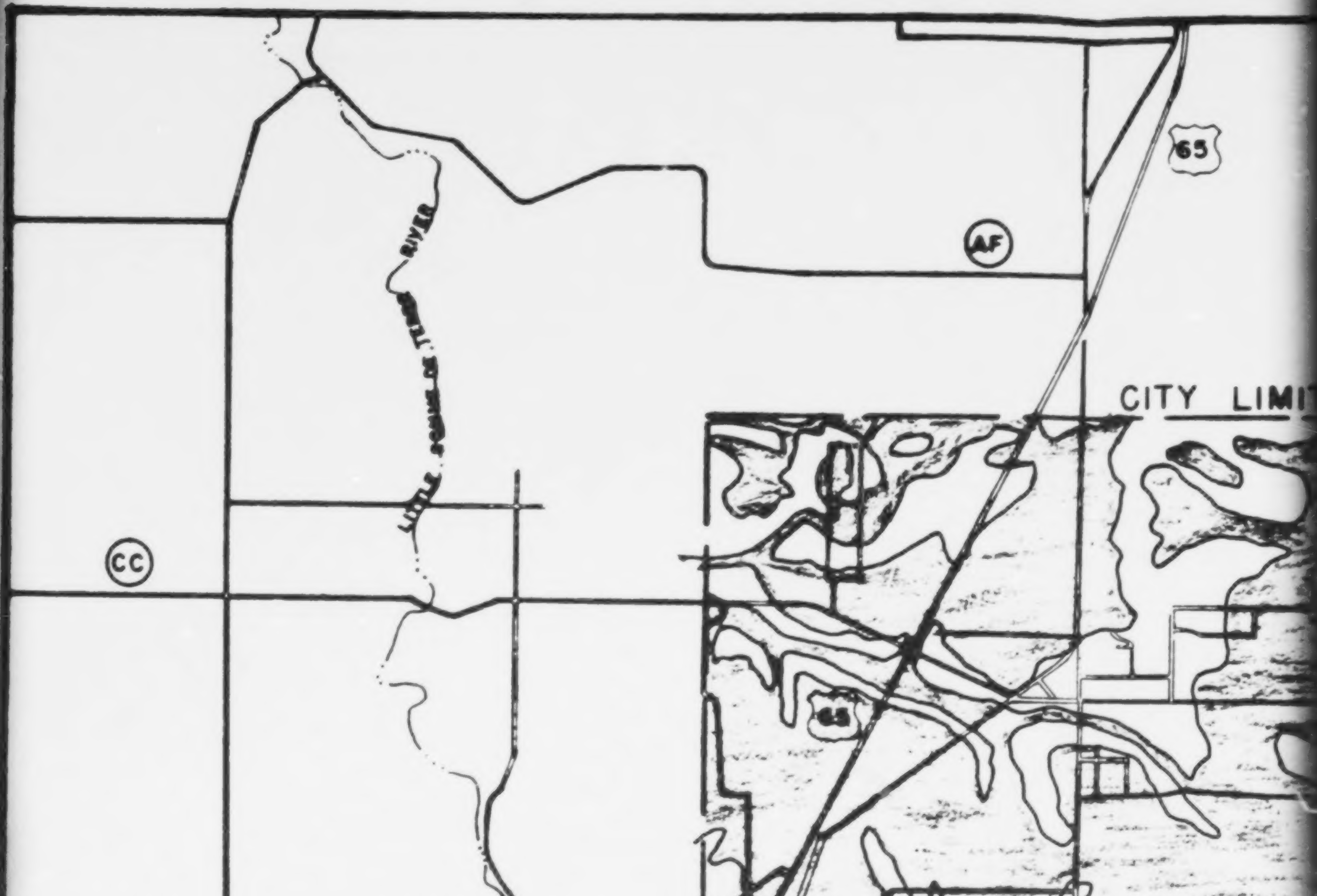
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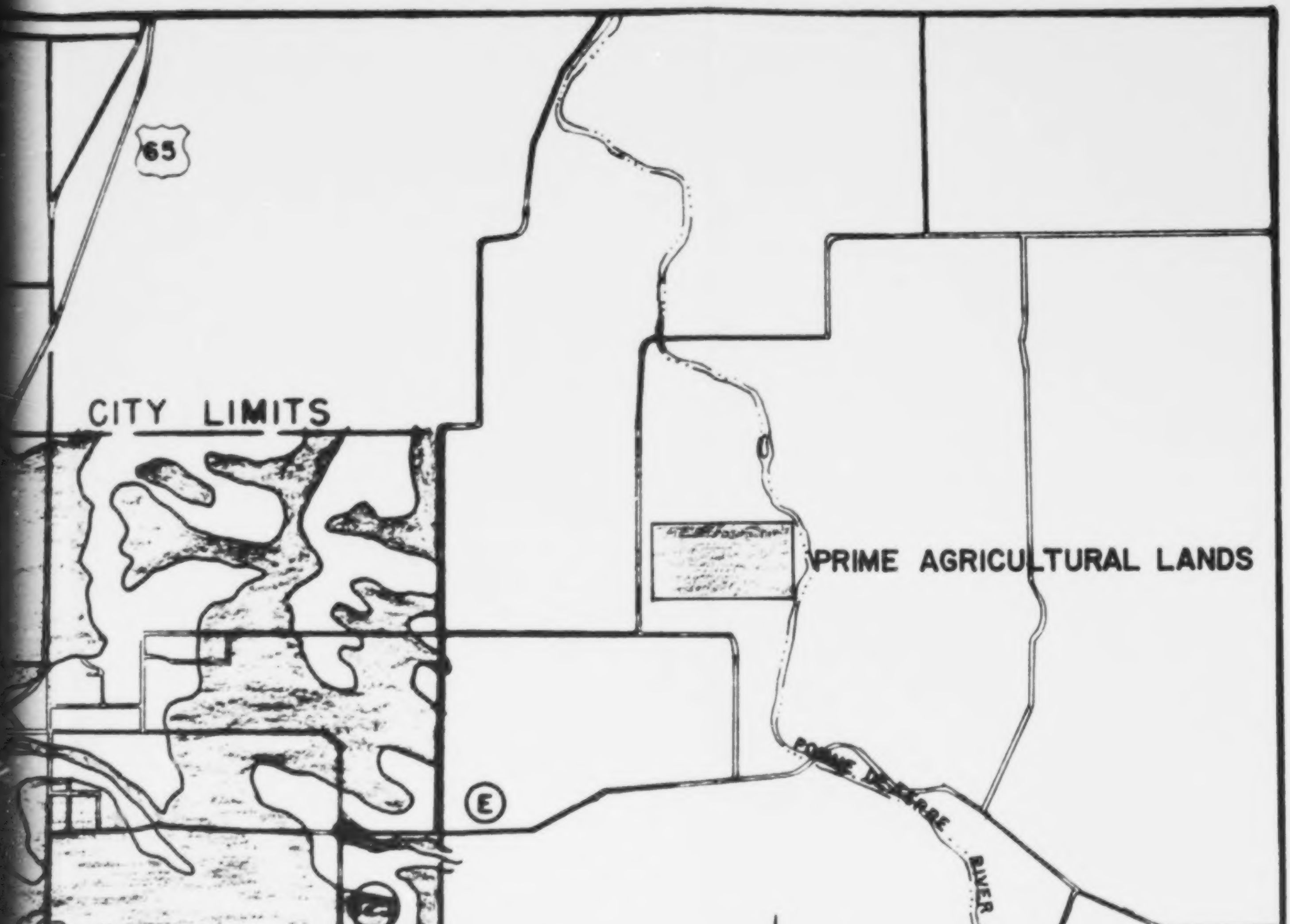
AF
CITY LIMIT
RIVER
LITTLE
CC
65



SCALE 1"=2000'

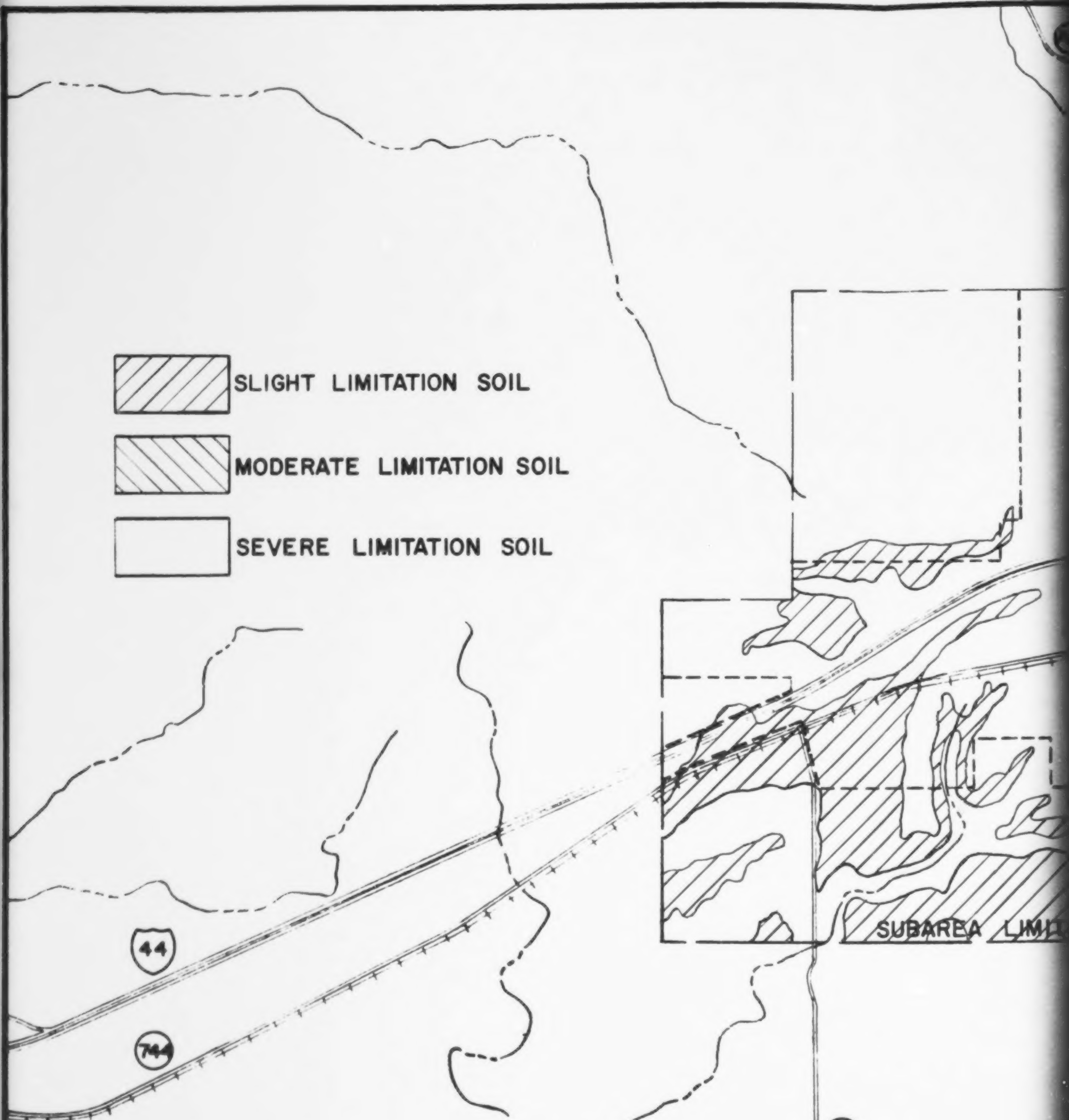
DEIS FIGURE A-8

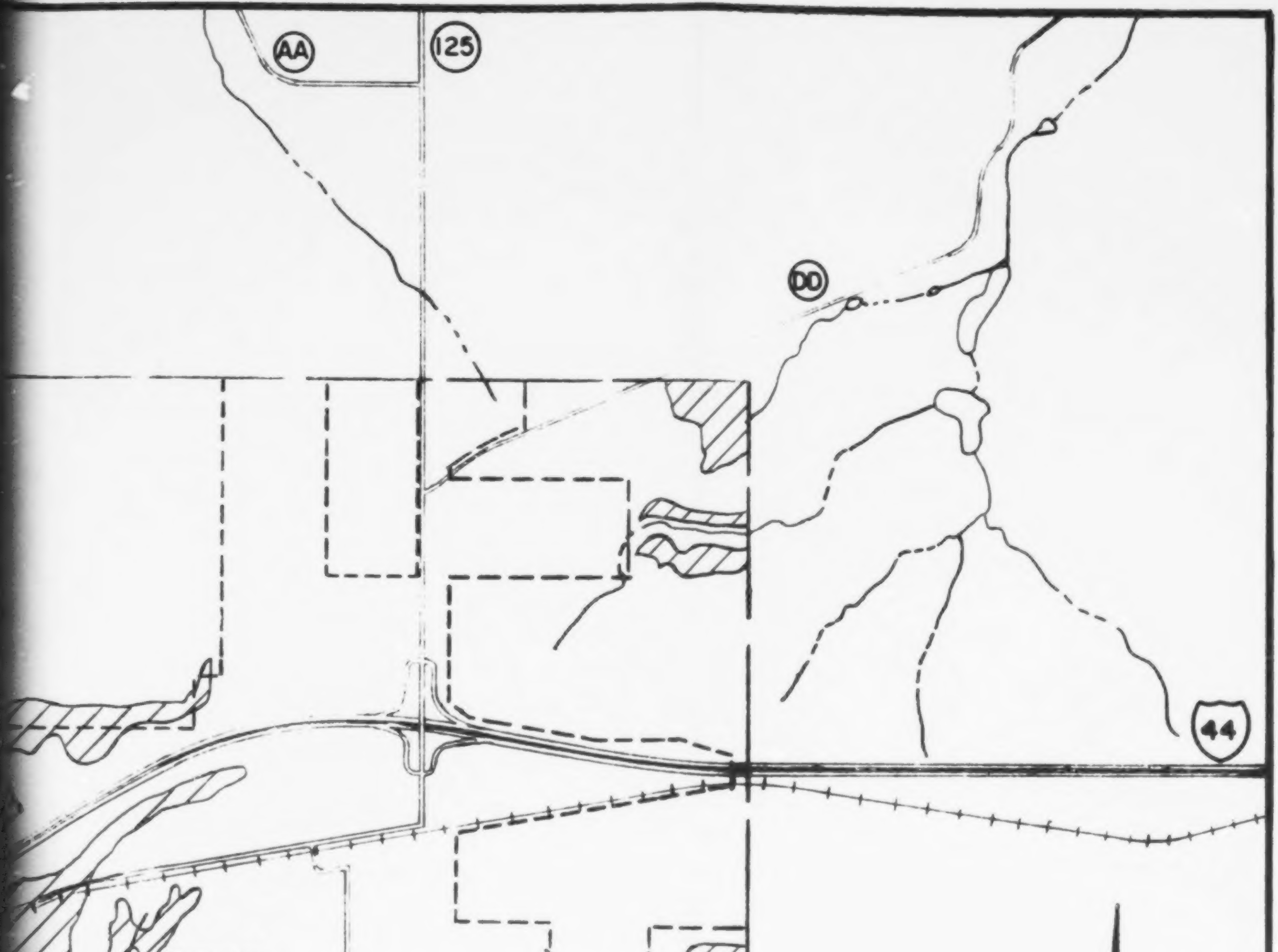
GREENE COUNTY SEWER DISTRICT

FAIR GROVE, MISSOURI SUBAREA

PRIME AGRICULTURAL LANDS

FIGURE # 3


SLIGHT LIMITATION SOIL
MODERATE LIMITATION SOIL
SEVERE LIMITATION SOIL
44
744
125
SUBAREA LIM



SCALE 1"=2000'

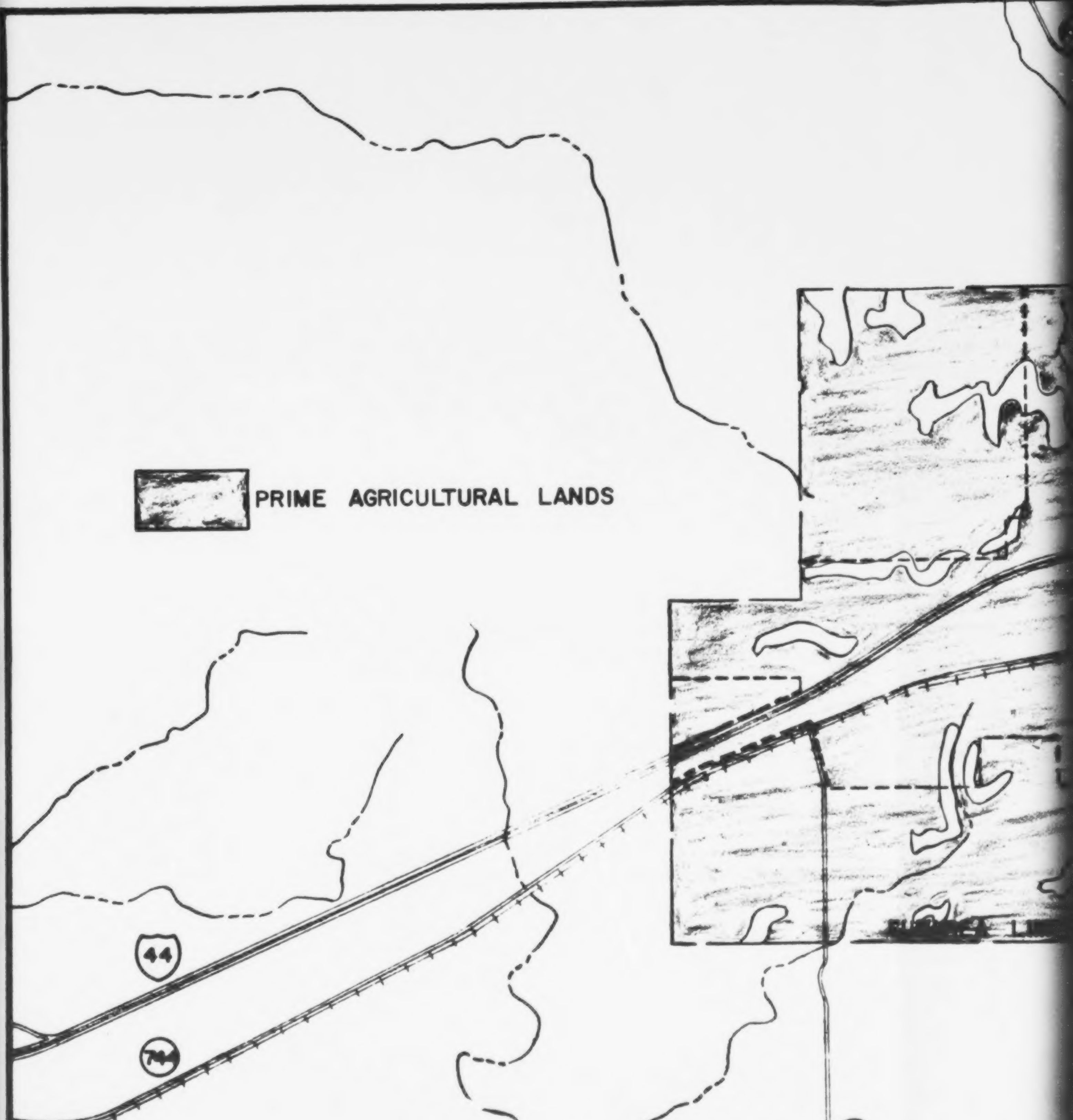
DEIS FIGURE A-9

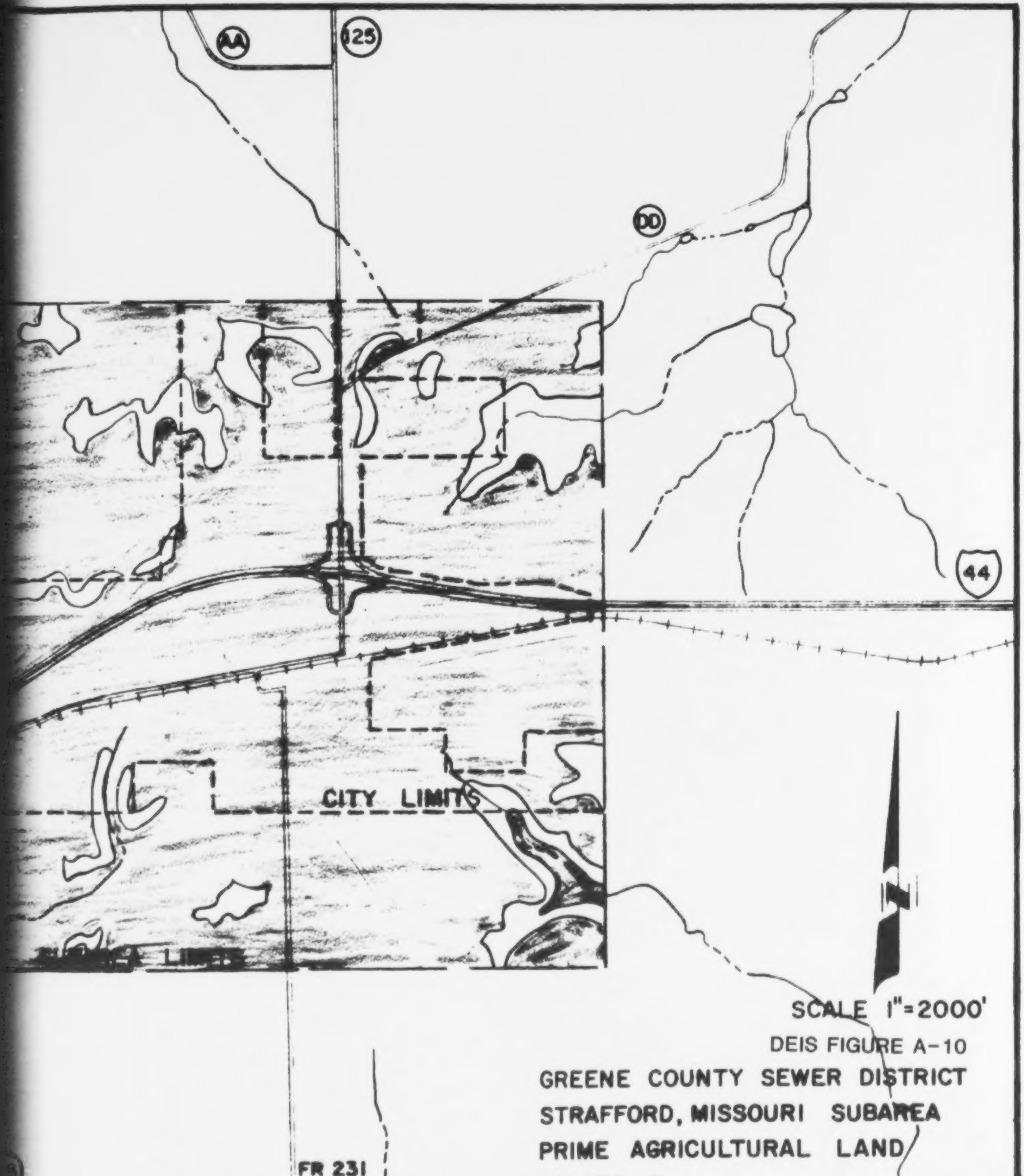
GREENE COUNTY SEWER DISTRICT

STRAFFORD, MISSOURI SUBAREA

SUITABILITY FOR SOIL ABSORPTION FIELD

FIGURE 4


PRIME AGRICULTURAL LANDS
44
744
125



DEIS FIGURE A-10

GREENE COUNTY SEWER DISTRICT
STRAFFORD, MISSOURI SUBAREA
PRIME AGRICULTURAL LAND
FIGURE 3

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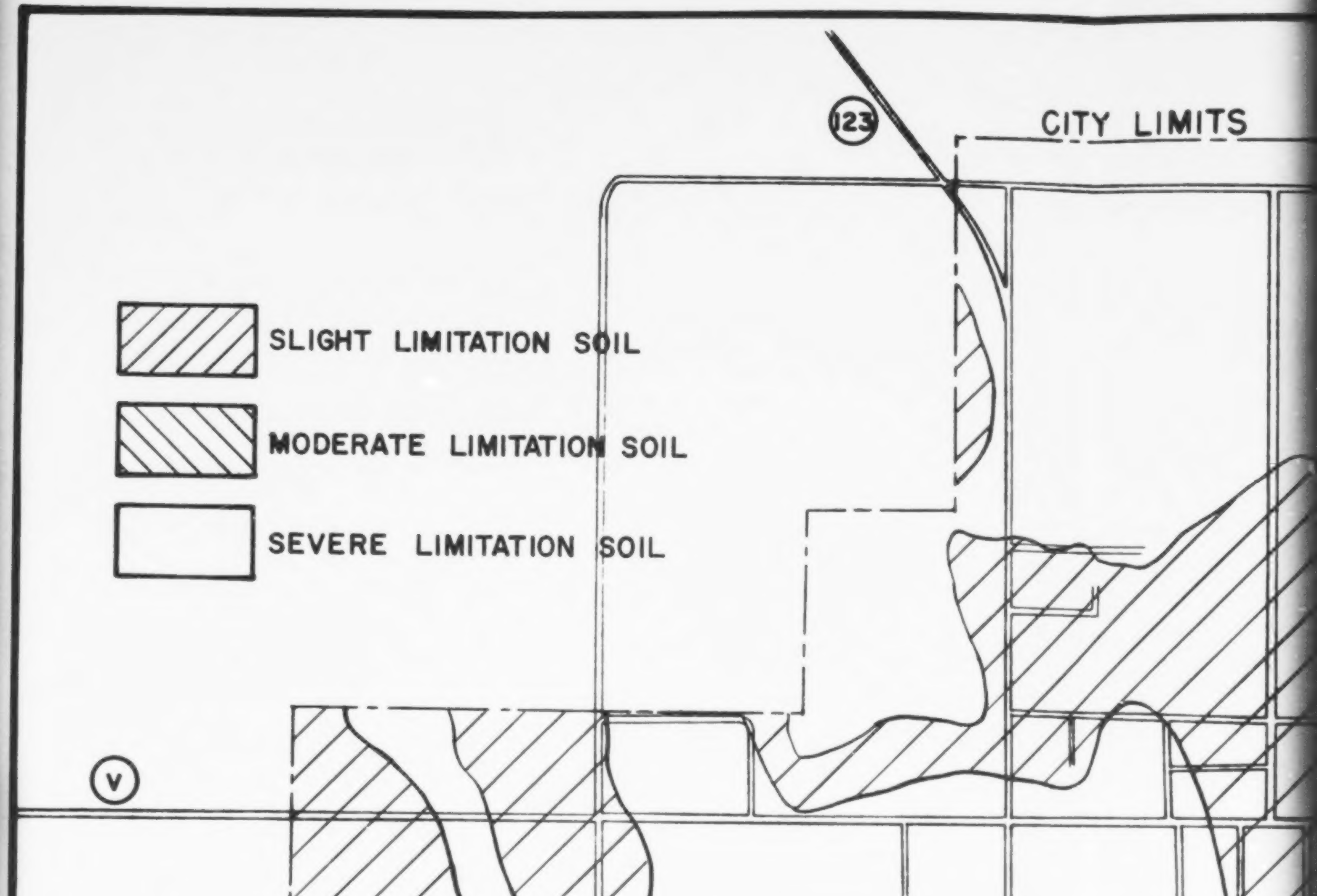
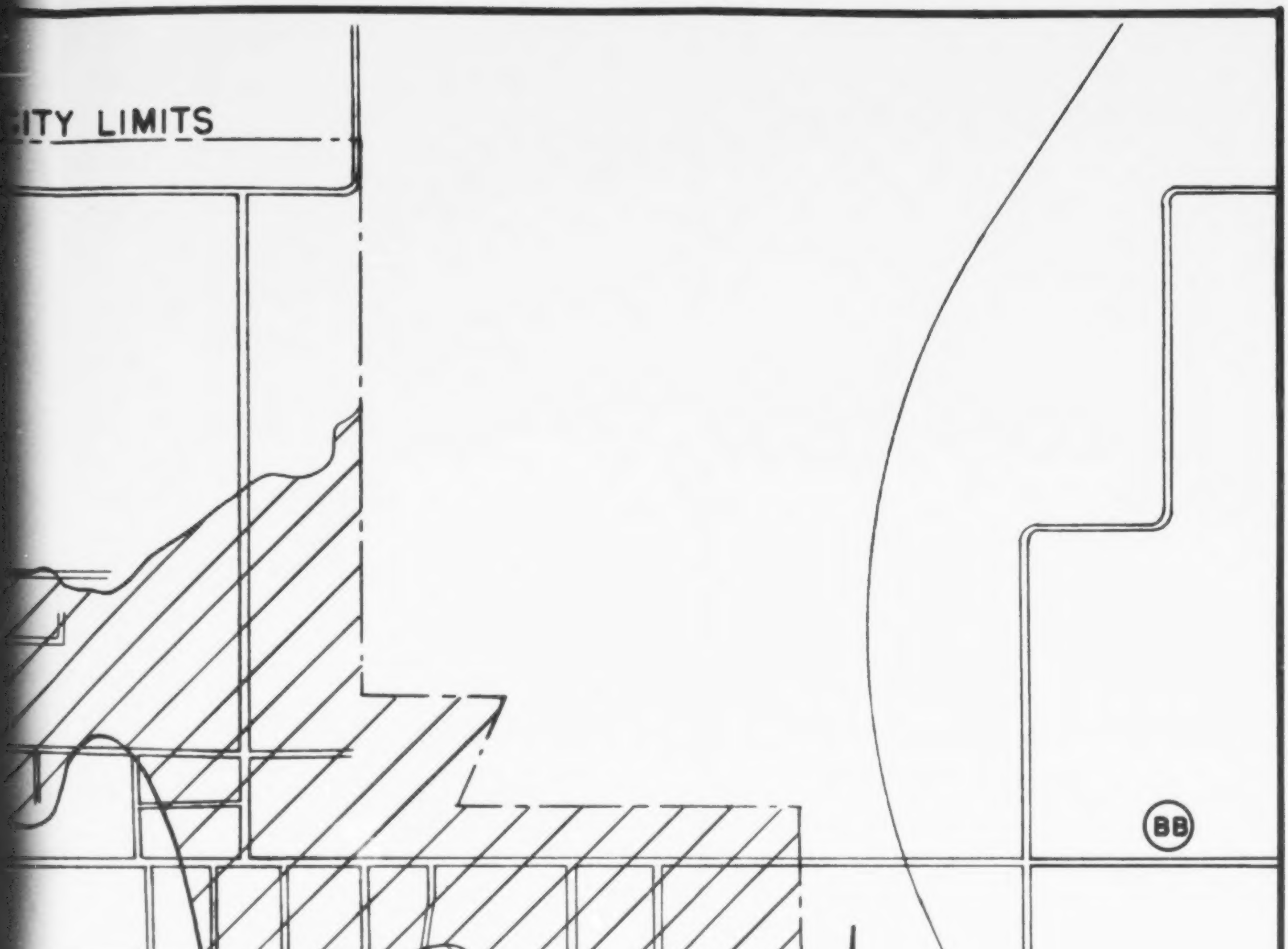

123
CITY LIMITS
▨ SLIGHT LIMITATION SOIL
▧ MODERATE LIMITATION SOIL
☐ SEVERE LIMITATION SOIL
V
123



DEIS FIGURE A-11

GREENE COUNTY SEWER DISTRICT
WALNUT GROVE, MISSOURI SUBAREA
SUITABILITY FOR SOIL ABSORPTION FIELD
FIGURE 4

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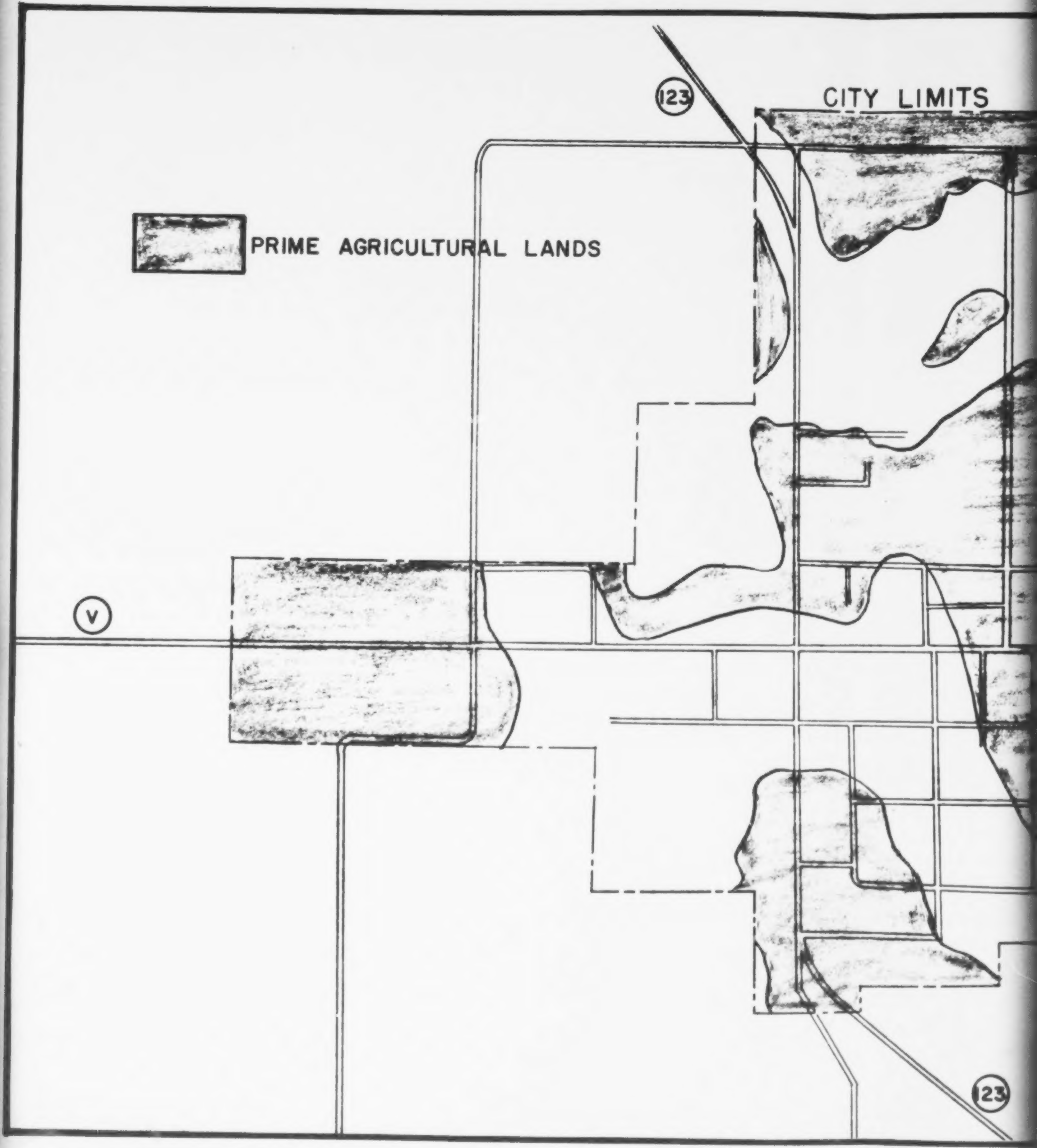
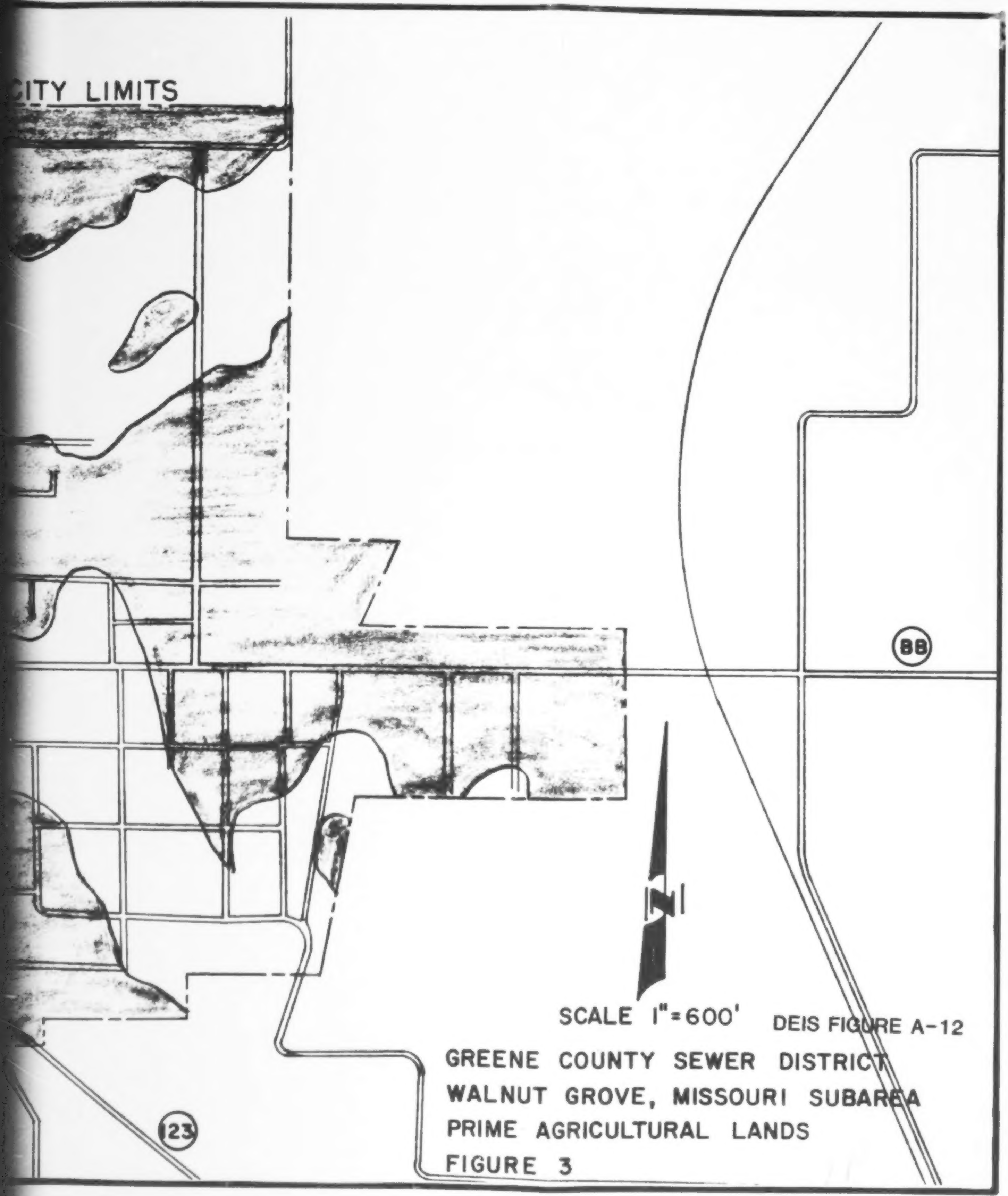

CITY LIMITS
123
PRIME AGRICULTURAL LANDS
V
123



SCALE 1" = 600' DEIS FIGURE A-12

GREENE COUNTY SEWER DISTRICT
WALNUT GROVE, MISSOURI SUBAREA
PRIME AGRICULTURAL LANDS
FIGURE 3

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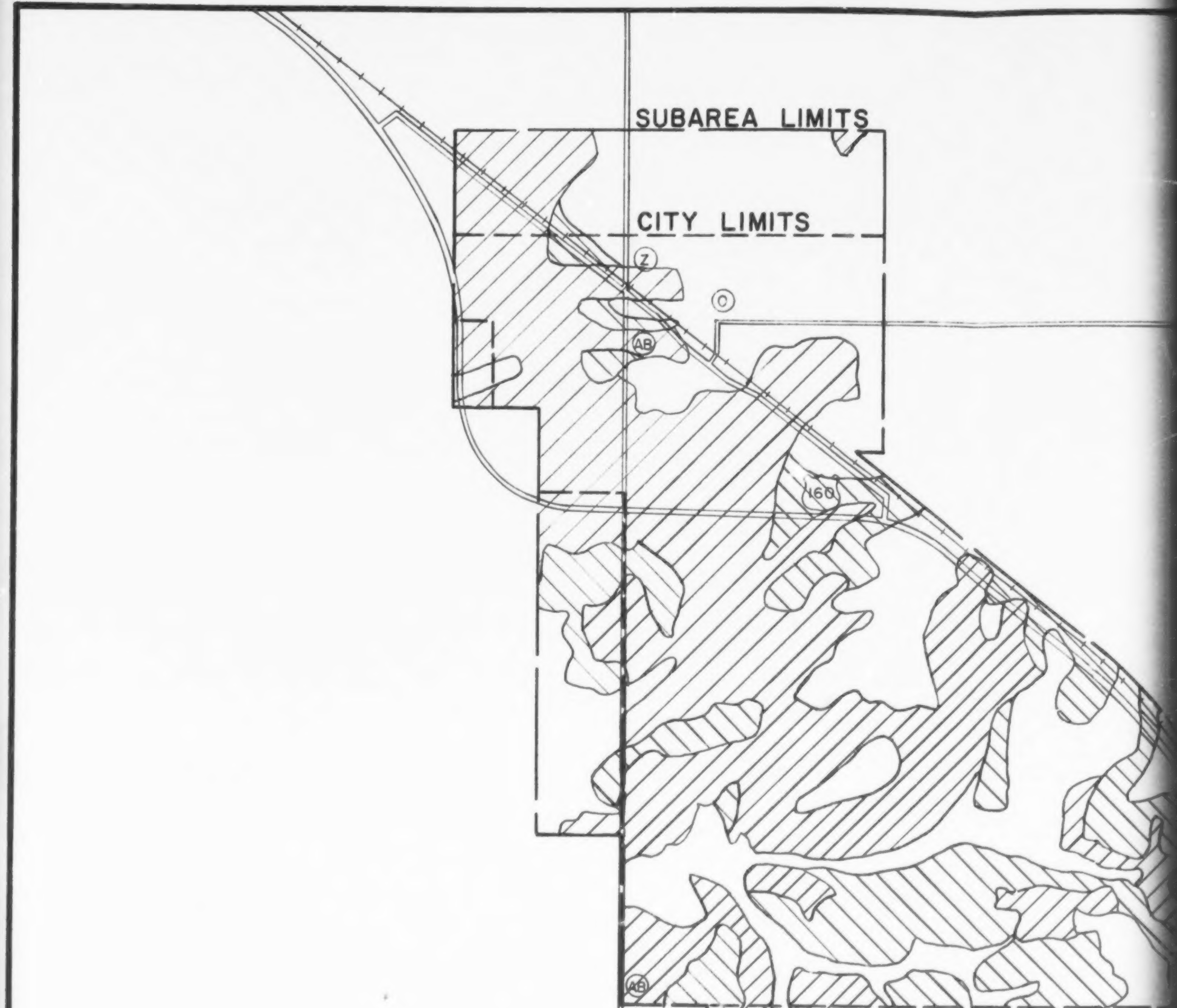
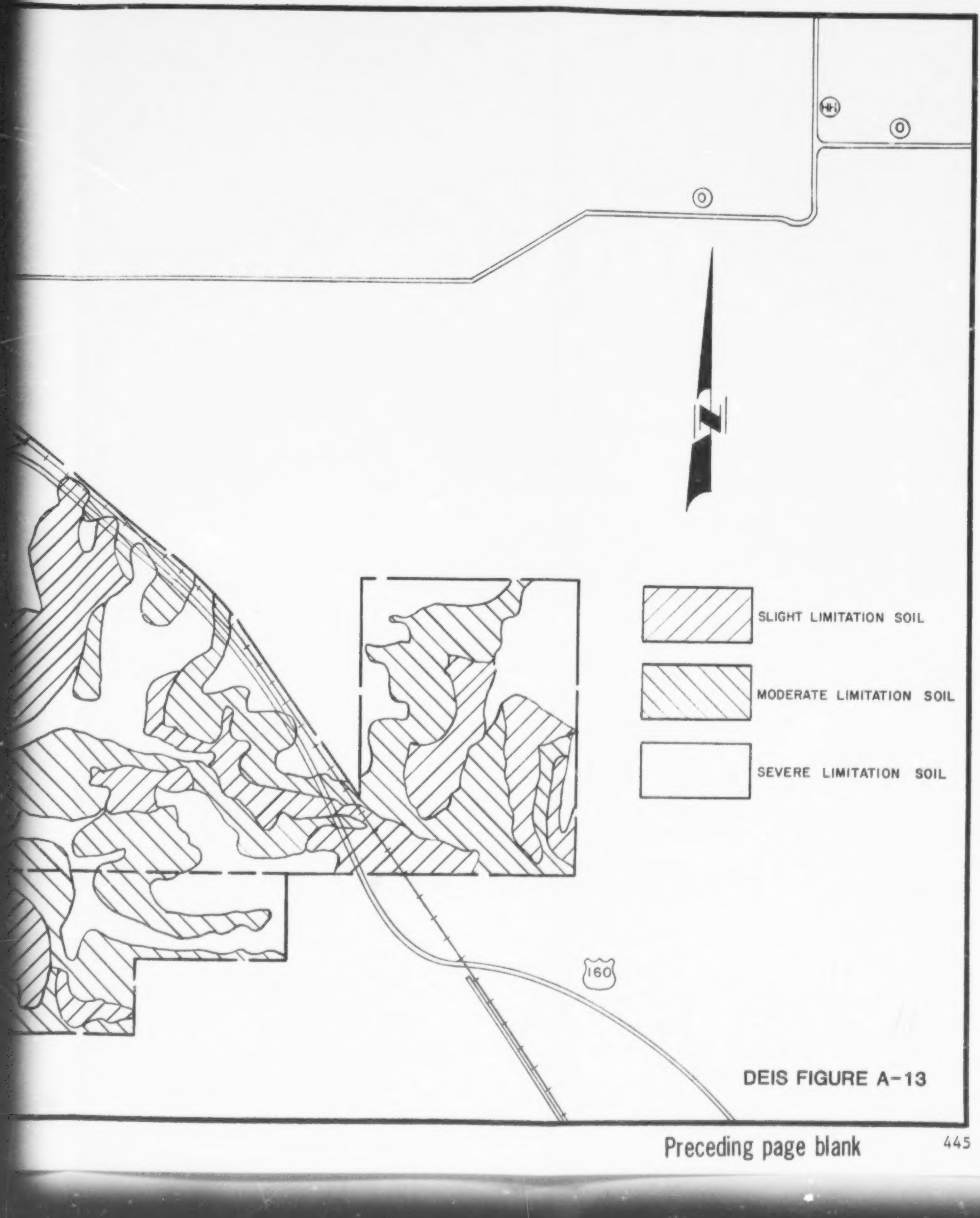


GREENE COUNTY SEWER DISTRICT
WILLARD, MISSOURI SUBAREA
SUITABILITY FOR SOIL ABSORPTION FIELD
FIGURE 4



DEIS FIGURE A-13

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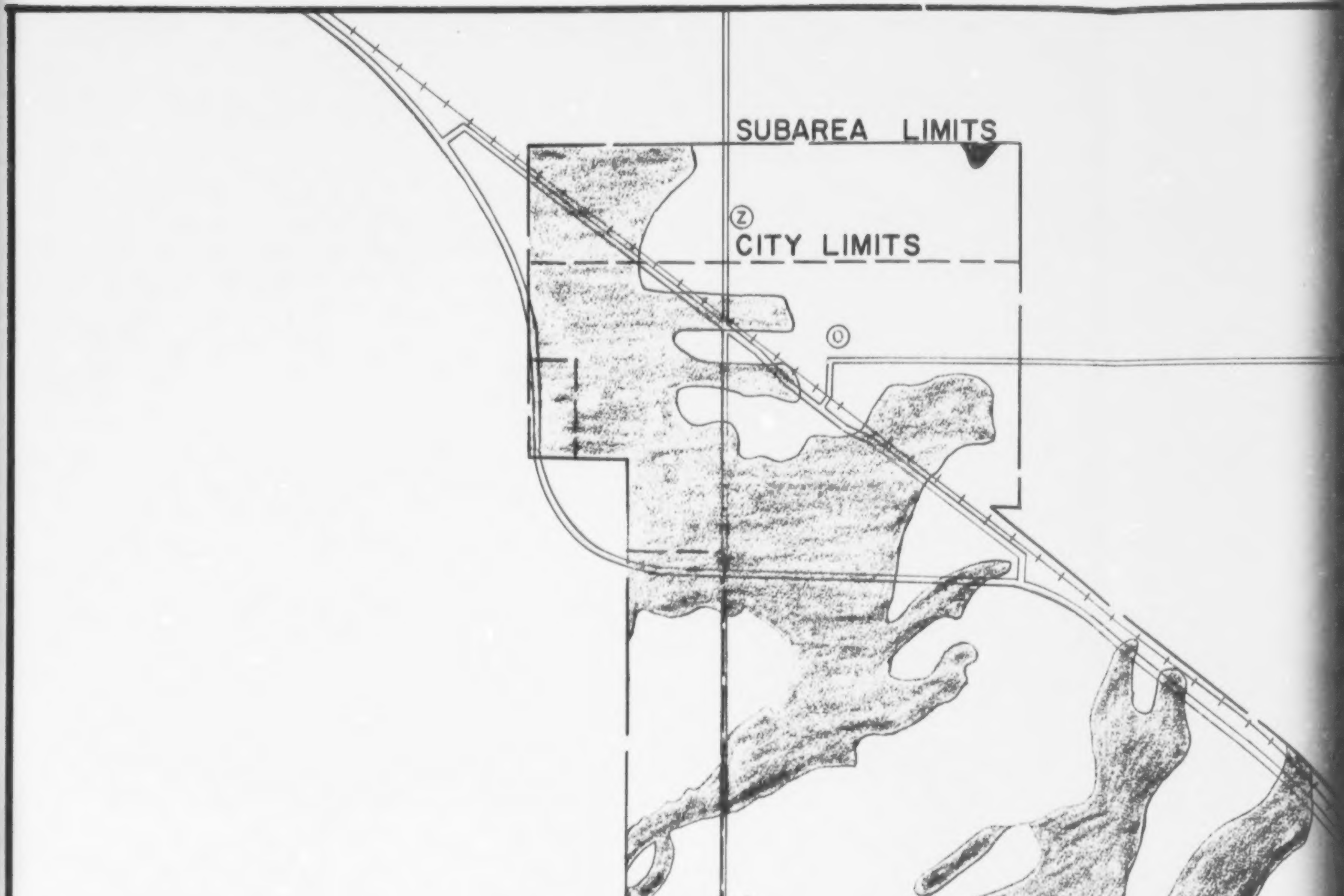
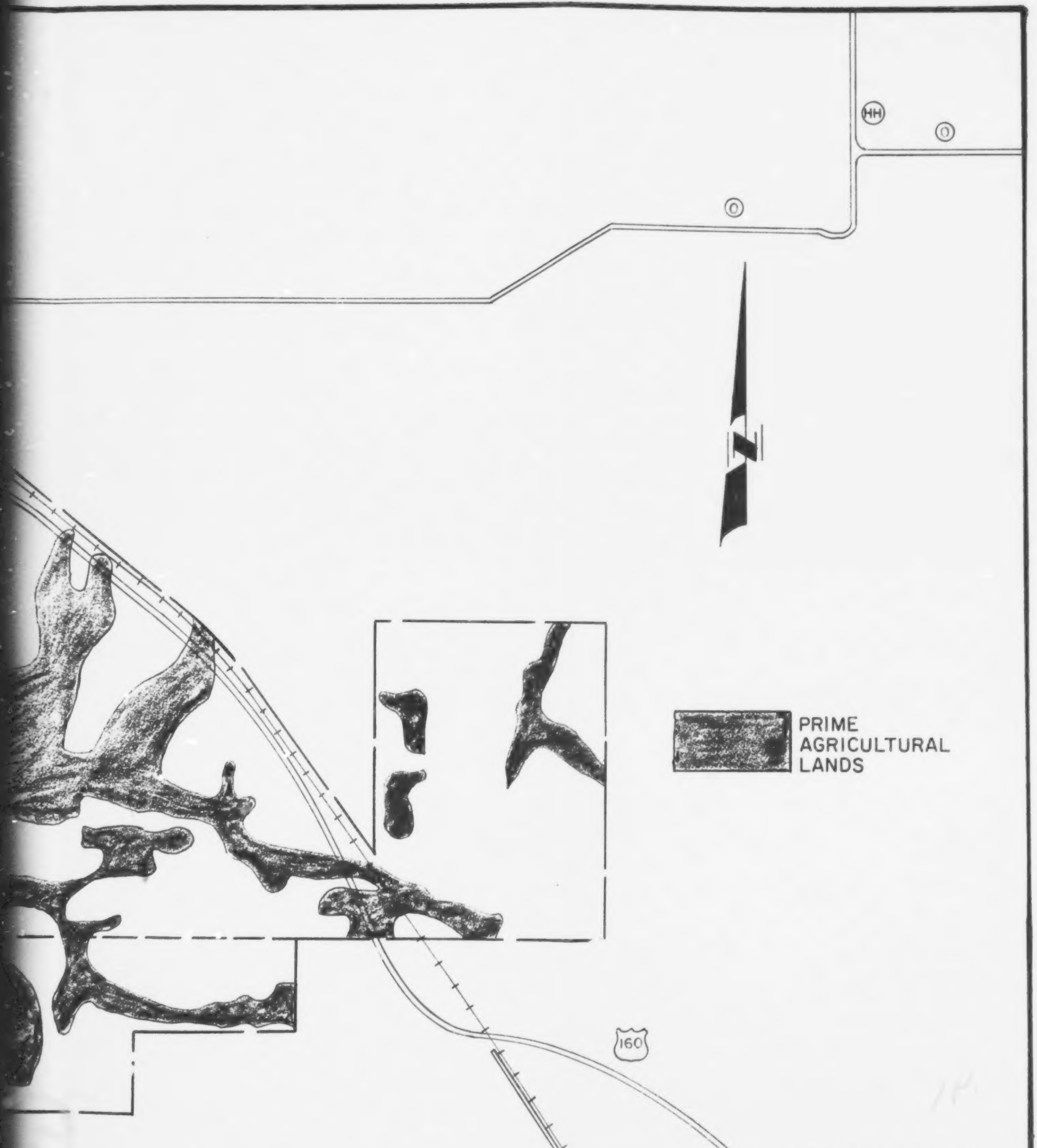


GREENE COUNTY SEWER DISTRICT
WILLARD, MISSOURI SUBAREA
PRIME AGRICULTURAL LAND
FIGURE 3



DEIS FIGURE A-14

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APPENDIX B - WATER RESOURCES

TABLE B-1
FLOODWAYS DATA

Cross Section	Stream Distance Above Mouth (Miles)	Approximate Floodway Width (Feet)	100-Year Flood Elevations*** (feet)
South Creek			
A	3.67	200	1235.0
B	4.65	45	1255.5
C	4.66	25	1255.6
D	5.49	150	1275.7
E	5.92	150	1283.5
South Branch Jordan Creek			
A	1.01	460	1300.3
B	1.47	55	1304.6
Jordan Creek			
A	14.45*	300	1229.5
B	15.05*	400	1241.2
Fassnight Creek			
A	0.19	200	1219.2
B	0.77	200	1231.0
C	1.06	200	1238.0
D	1.36	200	1243.8
E	1.90	200	1256.5
F	2.25	200	1264.8
James River			
A	92.52	1100	1153.2
B	92.88	300**	1154.8
C	93.27	220	1155.7
D	93.48	390	1156.8
Galloway Creek			
A	0.47	150	1159.6
B	0.92	150	1178.2
C	1.40	150	1189.5
D	1.70	150	1196.8
E	2.24	150	1214.0
F	2.45	150	1225.3

* Above mouth of Wilsons Creek.
** Width within corporate limits.
*** Natural flood elevations; encroachment elevations are 0.5 foot higher.

TABLE B-1 (continued)
FLOODWAYS DATA

Cross Section	Stream Distance Above Mouth (Miles)	Approximate Floodway Width (Feet)	100-Year Flood Elevations*** (feet)
Ward Branch James River			
A	3.62	150	1217.7
Doling Branch Pea Ridge Creek			
A	0	200	1180.7
B	0.20	175	1195.3
C	0.51	105	1217.3
D	0.63	150	1223.2
E	1.03	130	1232.6
Dickerson Branch Pea Ridge Creek			
A	0.20	200	1162.3
B	0.41	200	1177.7
C	0.75	150	1206.6
D	0.86	150	1210.7
E	1.10	130	1232.1
North Branch Jordan Creek			
A	0.16	400	1201.2
B	0.55	400	1211.6
C	0.84	400	1228.1
D	1.52	200	1237.8
Nichols Branch Wilsons Creek			
A	0.04	150	1228.9
B	0.19	140	1234.2
C	0.36	150	1240.4
D	0.62	150	1264.3
Wilsons Creek			
A	12.65	550	1209.8
B	13.32	600	1216.4

* Above confluence with South Branch of Jordan Creek.

** Natural flood elevations; encroachment elevations are 0.5 foot higher.

APPENDIX B

TABLE B-2
DISCHARGES OF MAJOR SPRINGS

Map. No.	Spring	Nearest Town	Land Line Location*	Rate of Flow 1000 gal per day	Temp °C	Date of Measurement	Use
1	Bigbee	Willard	SE, W½, Lot 2, NE 4,29,23W	207	14	10/27/64	Livestock
2	Brower	Willard	NE, E½, Lot 3, NW 4,29,23W	213	14	10/27/64	
3	Cave	Willard	SWSE 4,30,23W	26	14	11/5/63	
				76	15	8/25/64	
4	Clear Creek	Springfield	SWSW 3,29,23W	1190	15	9/23/64	Commercial
				988	14	12/2/64	
5	Davis	Springfield	SESE 2,29,22W	200	14	12/2/64	Park, swimming pool
6	Dawson (Upper)	Ash Grove	NESW 30,30,23W	162	14	10/27/64	
7	Fulbright	Springfield	NW, W½, Lot 4, NW 2,29,22W	2160	14	12/2/64	Springfield waterworks
8	Hammond	Willard	NWNE 9,30,23W	52	--	11/5/63	
				245	15	8/26/64	
				142	14	9/24/64	
9	J. Hart	Republic	NWNW 18,28,24W	1250	15	9/21/64	Livestock
				2380	14	12/1/64	
10	Hayes	Springfield	NESW 19,29,23W	982	15	9/23/64	Livestock
				1630	14	12/2/64	
11	Kelley	Ash Grove	NWSE 15,30,24W	103	14	9/24/64	Livestock
12	Leeper	Ash Grove	NESE 30,30,24W	142	14	9/24/64	Livestock
13	Mason	Bois D'Arc	NWSE 9,29,24W	491	14	9/24/64	Livestock
14	Panther	Halltown	SWNE 19,29,24W	446	15	9/23/64	Livestock
15	Parrish	Willard	SWSW 28,30,22W	245	--	8/26/64	Livestock
				207	14	10/26/64	
16	Ritter No. 1	Springfield	SE, E½, Lot, 1, NE 4,29,22W	362	14	9/26/53	
				801	14	10/28/64	
				1070	14	12/2/64	
17	Ritter No. 2	Springfield	SW, W½, Lot 4, NW 3 4,29,22W	762	15	10/28/64	
				1280	14	12/2/64	
	Ritter Nos. 1 & 2	Springfield		2220	16	8/26/64	(Combined Nos. 1 & 2)
18	Snider	Willard	NWNW 34,30,23W	174	16	10/27/64	Livestock
19	Trogdon	Republic	NWNE 21,28,24W	852	14	9/21/64	Livestock
				1240	14	12/1/64	

TABLE B-2 (Continued)
DISCHARGES OF MAJOR SPRINGS

Map. No.	Spring	Nearest Town	Land Line Location*	Rate of Flow 1000 gal per day	Temp °C	Date of Measurement	Use
20	Valley Water Mill	Springfield	NESE 5,29,21W	866	14	12/3/64	Springfield waterworks
21	Williams	Springfield	NENE 33,30,22W	730	14	10/28/64	Domestic, livestock
				885	14	12/2/64	
22	Blue	Nixa	NENE 32,28,22W	2150	--	10/23/28	
				1290	14	10/20/32	
				1030	--	7/7/53	
				1010	14	10/30/63	
				1490	14	8/27/64	
23	Camp Cora	Nixa	NESE 30,28,21W	698	14	8/30/55	
				517	15	10/29/63	
24	Danforth No.1	Strafford	SWSW 5,29,20W	239	16	10/29/64	Livestock
				446	14	12/1/64	Milk cooler
24	Danforth No.2	Strafford	SWSW 5,29,20W	465	14	10/29/64	Livestock
				575	14	12/1/64	
25	Hunt	Springfield	SWNW 24,28,21W	123	14	9/22/64	
26	Indian	Battlevield	SESE 29,28,22W	129	14	9/22/64	
27	Jones	Springfield	SWNE 27,29,21W				
	(Average of 10 measurements)			1620	--	1925-1965	
	(Maximum discharge measured)			7750	13	4/6/65	
	(Minimum discharge measured)			775	14	10/4/65	
				78	--	10/21/63	
28	Monroe	Springfield	NWNE 27,29,21W	459	15	8/27/64	
29	Rader	Springfield	SENW 18,28,22W	10500	23	8/4/64	
				988	18	10/20/64	
				6780	12	12/1/64	
				8660	9	1/20/65	
				23400	--	4/28/65	
30	Sequiota	Springfield	NENW 9,28,21W	11000	--	9/28/36	City park
				970	14	11/12/42	
				640	13	12/4/63	
				1600	18	8/27/64	
				1290	12	11/30/64	

TABLE B-2 (continued)
DISCHARGES OF MAJOR SPRINGS

Map. No.	Spring	Nearest Town	Land Line Location*	Rate of Flow 1000 gal per day	Temp °C	Date of Measurement	Use
31	Sherrod	Springfield	SESE 33,29,22W	220	--	11/23/56	
				207	--	12/13/56	
				149	--	9/2/60	
				297	16	8/2/64	
32	Ward	Springfield	SESE 14,28,22W	1120	15	9/22/64	Livestock
				659	14	12/1/64	
33	Welch	Springfield	SWNW 14,28,22W	116	17	9/22/64	Domestic
34	Winoka	Galloway	NWNW 22,28,21W	149	13	10/20/32	Private lodge water supply
				2090	--	3/7/37	
				3880	--	12/14/54	
				155	14	10/29/63	
				271	12	11/30/64	

* Read "NWNE 4,29,23W" as "northwest quarter of northeast quarter of Section 4, T29N, R23W."

Source: Vineyard (8).

APPENDIX C - AQUATIC ECOLOGY

TABLE C-1
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Longnose Gar	James, Sac	sluggish pools, backwaters; moderately clear streams	abundant
Gizzard Shad	James, Sac	quiet water, lakes, ponds, backwaters	abundant
Rainbow Trout	James, Sac	streams, lakes, reservoirs, 70°F water	abundant
Grass Pickerel	James, Sac	sluggish sections of streams and ditches; small headwater creeks with permanent pools, clear water; heavy vegetation	abundant
Carp	James, Sac	large streams; lakes that are highly productive; deep pools	very abundant
Goldfish	James, Sac	no self-sustaining population	
Golden Shiner	James, Sac	quiet water, sloughs, ponds, lakes, permanent pools	abundant
Creek Chub	James, Sac	small headwater creeks with few other fish	abundant
Southern Redbelly Dace	James, Sac	clear cool water; silt-free, gravelly bottoms	abundant
Hornyhead Chub	James, Sac	clear, permanent streams with clean, gravelly or rubble bottoms	abundant

TABLE C-1 (Continued)
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Bigeye Chub	James	clear, permanent streams with clean, gravel or rubble bottoms; occurs near riffles	common
Streamline Chub	James	continuous strong flow of clear water, gravel bottoms	abundant
Bigeye Shiner	James	moderately clear stream, permanent pools; avoids cooler water and strong current	abundant
Rosyface Shiner	James, Sac	clear streams, permanent flow, near riffles or in pools with currents	abundant
Telescope Shiner	James	near riffles; gravel or rock bottoms	abundant
Duskystripe Shiner	James	continuous strong flow, near riffles; clean gravel bottom	abundant
Striped Shiner	James, Sac	clear permanent flowing streams; gravel or rock bottoms	abundant
Wedgespot Shiner	James	larger, clear, permanent streams near riffles	common
Whitetail Shiner	James	continous strong flow, firm silt-free bottoms; avoids continuous cool discharge	common
Ozark Shiner	James	large clear streams with permanent strong flow	rare in James River system
Ozark Minnow	James, Sac	permanent flowing streams with pools or backwaters, gravel bottom	abundant

TABLE C-1 (Continued)
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Bluntnose Minnow	James, Sac	clear, warm water, permanent flow in quiet pools and backwaters	abundant
Fathead Minnow	James, Sac	small, intermittent prairie streams	spotty - from bait bucket releases
Checkered Madtom	James	permanent strong flow in quiet pools near deposits of organic debris	common
Flathead Catfish	James, Sac	variety of streams types	common
Ozark Cavefish	James, Sac	in caves and spring outlets	extremely rare
Southern Cavefish	James, Sac	in caves and spring outlets	extremely rare
Northern Studfish	James, Sac	clear water, silt-free margins of pools and riffles with little current	abundant
Blackspotted Topminnow	James, Sac	clear flowing and quiet water with aquatic vegetation	abundant
Brook Silverside	James, Sac	clear, warm water with no current	abundant
Mottled Sculpin	James, Sac	spring branches, riffles pools	common
Banded Sculpin	James, Sac	spring branches	common
Smallmouth Bass	James, Sac	clear, cool, flowing streams, near riffles	abundant

TABLE C-1 (Continued)
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Largemouth Bass	James, Sac	lakes, permanent pools; warm, clear water	abundant
Green Sunfish	James, Sac	variety of stream types	common
Longear Sunfish	James, Sac	clear flowing water, pools, inlets; avoids strong currents	abundant
Bluegill	James, Sac	deeper pools and backwaters; warm, clear water	abundant
Rock Bass	James, Sac	streams with permanent flow; clear water; slight - moderate current	abundant
White Crappie	James, Sac	reservoirs with standing timber	rare
Black Crappie	James, Sac	reservoirs with standing timber	common
Walleye	James, Sac	lakes, reservoirs, large pools	abundant
Logperch	James, Sac	large permanent pools; deeper riffles, avoids turbidity	common
Gilt Darter	James	clear, flowing streams with silt-free bottoms	common
Speckled Darter	James	quiet pools and backwaters	common
Banded Darter	James	rocky riffles, permanent	abundant
Greenside Darter	James, Sac	swift, gravel riffles	abundant

TABLE C-1 (Continued)
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Yoke Darter	James	strong flow, riffles with swift current	abundant
Stippled Darter	James, Sac	spring branches, clear water, permanent flow	rare
Rainbow Darter	James, Sac	rocky, gravelly riffles, permanent flow	abundant
Orangethroat Darter	James, Sac	sluggish riffles, spring branches, clear water	abundant
Fantail Darter	James, Sac	rocky and gravelly riffles, permanent flow	rare
Freshwater Drum	James, Sac	large rivers, lakes, and impoundments	scarce
Mooneye	Sac	large pools in streams; open waters in reservoirs	common
Gravel Chub	Sac	clear to turbid streams with permanent flow, gravel bottom	common
Sucker Mouth Minnow	Sac	warm, clear, permanent flowing streams, gravel riffles	abundant
Redfin Shiner	Sac	permanent pools; gravel or rock bottoms, with intermittent flow	abundant
Bleeding Shiner	Sac	clear streams with continuous flow; gravel or rock bottom	abundant
Red Shiner	Sac	large creeks and rivers with quiet pools and backwaters avoids cool clear waters	abundant

TABLE C-1 (Continued)
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Sand Shiner	Sac	large rivers; shallow pools with permanent flow; clear water with sandy bottoms	abundant
Silver Redhorse	Sac	large deep or large streams, permanent flow; rock or gravel bottom	common
Shorthead Redhorse	Sac	permanent, strong flow, gravel or rock bottom; riffles or pools	abundant
Stonecat	Sac	rocky riffles, sandy bottom	abundant
Orangespotted Sunfish	Sac	turbid, intermittent flow, avoids streams with cool clear	abundant
Slenderhead Darter	Sac	gravel or rock bottom, strong flow, swift current	abundant
Johnny Darter	Sac	quiet pools, avoid streams with excessive turbidity	common
Missouri Saddled Darter	Sac	clear, high gradient streams with continuous strong flow, gravel and rock bottom	abundant
Niangua Darter	Pomme de Terre	Clear, permanent streams; gravel or rock bottoms, rock pools	rare
Central Stoneroller	James, Sac	gravel or rock bottoms, riffles permanent flow	abundant
Largescale Stoneroller	James, Sac	Gravel, rubble or bedrock riffles; permanent flow	abundant

TABLE C-1 (Continued)
FISH FAUNA OCCURRING IN THE PLANNING AREA

Fish	River System	Habitat	Abundance
Highfin Carpsucker	James, Sac	clear water, firm bottom	common
White Sucker	James, Sac	small creeks, gravel bottom riffles, spring branches	common but spotty
Northern Hog Sucker	James, Sac	riffles, pools, gravel or rock bottoms with permanent flow	abundant
Black Redhorse	James, Sac	clear permanent streams, gravel or rock bottom	abundant
Golden Redhorse	James, Sac	warm, clear water, permanent flow; gravel or rock bottom	common
River Redhorse	James, Sac	clear pools; streams with continuous strong flow; gravel bottom	relatively rare
Creek Chubsucker	James	clear quiet water with submerged vegetation	relatively rare
Black Bullhead	James, Sac	turbid water, silt bottom, no current	common
Channel Catfish	James, Sac	Large pools around submerged objects	abundant
Slender Madtom	James, Sac	clear water, permanent flow, riffles	scarce
Ozark Madtom	James	riffles, rocky pools; permanent flow	abundant

TABLE C-2
BENTHOS COLLECTED IN THE JAMES RIVER AND WILSONS CREEK FROM JUNE TO DECEMBER, 1978

	James River Station 1 (above Lake Springfield)	James River Station 2 (below Lake Springfield)	Wilsons Creek (below S.W. treatment plant)
No. of Taxa =	65	45	22
Avg. Species Diversity =	4.02	3.60	2.42

James River Station 1 (above Lake Springfield)		James River Station 2 (below Lake Springfield)		Wilsons Creek (below S.W. treatment plant)
Baetis sp.	P. placida	Baetis sp.	P. herricki	Baetis sp.
Pseudocloeon sp.	I. varians	E. simulans	C. cornutus	S. pulchellum
Caenis sp.	Isoperla sp.	Heptagenia sp.	Sialis sp.	S. tripunctatum
E. simulans	S. fasciata	S. interpunctatum	A. variegata	A. moesta
H. limbata	T. maura	S. nepotellum	Ablabesmyia sp.	A. plana
Heptagaenia sp.	H. lithophilus	S. pulchellum	Orthocladius sp.	A. tibialis
S. interpunctatum	M. glabaratus	S. terminatum	Polypedilum sp.	E. civile
S. nepotellum	Stenelmis sp. larvae	S. tripunctatum	Simulium sp.	Stenelmis sp. larvae
S. pulchellum	S. beameri	Leptophlebia sp.	Chrysops sp.	S. crenata
S. terminatum	S. crenata	E. album	Hexatoma sp.	P. herricki
S. tripunctatum	S. exigua	P. myops	Cheumatopsyche sp.	C. cornutus
Choroterpes sp.	S. lateralis	Isonychia sp.	H. arinale	Ablabesmyia sp.
Leptophlebia sp.	E. nervosa	Tricorythodes sp.	H. scalaris	Chironomus sp.
E. album	P. herricki	H. americana	H. simulans	Cricotopus sp.
P. myops	C. cornutus	A. moesta	P. flava	Cryptochironomus sp.
Isonychia sp.	Sialis sp.	Enallagma sp.	C. obscura	Dicrotenipes sp.
Tricorythodes sp.	A. variegata	N. clymene	P. flavida	Polypedilum sp.
A. moesta	Ablaesmyia sp.	P. capitata	Paragyrarctis sp.	Tanytarsus sp.
L. albistylus	Cardiocladius sp.	P. placida		Hemerodromia sp.
A. granulata	Chironomus sp.	T. maura		Simulium sp.
A. evoluta	Cricotopus sp.	O. sandersoni		Chrysops sp.
N. clymene	Cryptochironmus sp.	Stenelmis sp. larvae		Cheumatopsyche sp.
P. capitata	Diamesa sp.	S. beameri		
Microtendipes sp.	Eukiefferiella sp.	S. crenata		
Orthocladius sp.	Tipula sp. #1	S. exigua		
Polypedilus sp.	Tipula sp. #2	S. lateralis		
Stictochironomus sp.	H. borealis	Dineutus sp.		
Tanytarsus sp.	Cheumatopsyche sp.			
Tribelos sp.	H. arinale			
Hemerodromia sp.	S. (bifida gp)			
Simulium sp.	C. aterrima			
Chrysops sp.	C. obscura			
	C. socia			

* Shannon-Weaver Index

TABLE C-3
CHARACTERISTIC PLANTS OF SPRINGS

Sparganium americanum
Potamogeton amplifolius
Potamogeton lucens
Potamogeton crispus
Potamogeton foliosus var. *genuinus*
Potamogeton foliosus var. *macellus*
Potamogeton panormitanus var. *major*
Potamogeton panormitanus var. *minor*
Zannichellia palustris var. *major*
Anacharis occidentalis
Poa annua var. *reptans*
Eleocharis acicularis var. *typica*
Eleocharis acicularis var. *gracilescens*
Lemna trisulca
Wolffia punctata
Polygonum hydropiperoides
Rorippa Nasturtium-aquaticum
Cardamine bulbosa fontinalis
Ceratophyllum demersum
Ranunculus longirostris
Callitriche heterophylla
Ludrigia palustris var. *americana*
Myriophyllum heterophyllum
Veronica connata var. *glaberrima*

TABLE C-4
INVERTEBRATES OF COLD SPRINGS IN THE SOUTHWESTERN MISSOURI OZARKS

Flatworms

- *Dugesia doratocephala*

Amphipods:

- *Bacturus muacronatus*
- *Crangonyx forbesi*
- *Gammarus pseudolimnaeus*
- *Stygonectes clantoni*
- *Stygonectes ozarkensis*

Isopods:

- *Asellus antricolus*
- *Asellus brevicauda brevicauda*
- *Lirceus garmani*
- *Lirceus hoppinae*

Crayfish:

- *Cambarus setosus*

Caddisflies:

- *Glossosoma intermedium*
- *Glyphosyche missouri*
- *Hydropsyche piatrix*
- *Microsema ozarkana*
- *Pycnopsyche subfaciata*
- *Setodes vernalia*

Stoneflies:

- *Allocapnia pygmaea*

Snails

- *Goniobasis potosiensis*

APPENDIX D - TERRESTRIAL ECOLOGY

Section 1. Ozark Plant Association

a. Sugar Maple-Bitternut Hickory Association. The sugar maple-bitternut hickory association is the climax stage of floodplain flora development. The developmental stages or associes of this association correlate with the development of the stream. Alluvial soils found in the development of the floodplain flora are usually neutral in pH. However, while a wide variety of plants occur here, plant species of alkaline soils often dominate. In this area of the Ozarks, the first stage of the floodplain association occurs when the stream is small with a rocky bed loaded with gravel deposits. Dominant trees are Ward's willow and sycamore. Herbs expected to occur on most gravel bars and along banks of streams include species of ragweed, sedge, day-flower, tick trefoil or beggars lice, lovegrass, flowering and nodding spurge, poverty grass, and crabgrass.

The Ward's willow-sycamore associes is followed by a second developmental stage of buttonbush, black willow, silver maple, green ash, and elm. Herbs such as clear weed, white woodland aster, golden glow, and white grass are common. These first two associes are subject to sudden stream overflows and variations of water level; therefore, the flora is not diverse, is late in developing, and is composed of annuals and water-tolerant types. With each stage the soils become richer through the addition of a deep humus layer mixed with sandy alluvium, and a greater number of shade-tolerant trees and shrubs appear.

The final developmental stage is dominated by sugar maple and bitternut hickory. One or two understories of shrubs are usually found in this associes. The pawpaw and American hornbeam are dominant small trees forming an upper portion of the understory, while buck brush or coralberry is a dominant lower shrub. Flowering dogwood is often abundant, as are spicebush and greenbrier. Sycamore is a very common species throughout floodplain development and persists into the very last associes. Together with sugar maple and bitternut hickory, elm, ash, and sycamore are the dominant species in the final associes of the floodplain flora. Birch likewise persists, but is most abundant adjacent to the river. Black willow and buttonbush do not occur in this final stage but are scattered near the water's edge. Other common trees and shrubs found in the sugar maple-bitternut hickory associes are included in Table D-1. Some of the herbs common to the final floodplain stage are ironweed, hog peanut, wild ginger, wood mint, Joe-Pye weed, white snakeroot, jewel weed, blue phlox, Virginia creeper, bloodroot, and smooth yellow and pale violets.

b. Sugar Maple-White Oak Association. The first stage of this association takes place on bare, rocky limestone glades, or openings where the surface is covered by exposed rock and residual fragments giving rise to an akaline soil type. The flora is dominated by herbaceous prairie species, with the first stage the side-oats grama/ black-eyed Susan associes. Many other herbaceous plants are commonly found. In the spring there are Missouri primrose, blue wild indigo, sandwort, wild hyacinth, purple cornflower, and yellow cornflower. In summer, the conspicuous dominants are false aloe, Evolvulus nuttallinus, purple prairie clover, centaury, heliotrope, Tragia ultricifolia, hogwort, and calamint. In the autumn the prevailing species are oblongleaf aster, silky aster, wild onion, and perennial black-eyed Susan. Switch grass, melic grass, side-oats gramma, and big and little bluestem predominate among perennial grasses, while poverty grass and witch grass are dominants among annual grasses.

Where glades and eroded limestone slopes face west or south, the dry sun and wind conditions create an environment favorable for the development of an herbaceous rather than a forest coverage. In these areas a pioneer herbaceous stage may last indefinitely. On east- and north-facing slopes, more moisture and protection against prevailing winds exist, and soil building goes on at a relatively fast pace. Thus, the succession taking place on north- and east-facing slopes culminates in the climax sugar maple-white oak associes at a more rapid rate than that taking place on a south- and west-facing area.

Following the pioneer seral stage of herbaceous flora, woody plants such as fragrant sumac, redcedar, and persimmon occur. Redcedar is usually the most dominant, often forming "cedar glades" that are characteristic of eroded limestone slopes and knobs. The ground cover is sparse beneath the redcedars, but melic and poverty grass, and big and little bluestem grasses are usually found on open areas in this associes (127).

With the gradual rock disintegration and increase of soil, an incursion of shrubs appears, and the chittimwood-black haw associes follows. While these two species are dominant, greenbrier, supplejack, hawthorn and hackberry are also present. Once this stage is reached, other shrubs and trees rapidly cover the glade shading out the redcedar.

A winged elm-Indian cherry associes usually follows and includes such species as the southern hackberry, stunted white ash, and possum haw. This is quickly followed by a chinquapin oak-white ash associes which dominates west- and south-facing slopes. This associes has a variety of other shrubs which include hop hornbeam, redbud, slippery and winged elms, and blue ash.

As more soil is formed over the limestone substratum which originally was an open glade, sugar maple makes its appearance and finally, with white oak, attains dominance in the last stage of development--the sugar maple-white oak associes. Other common species in this climax associes are northern red oak, linden and butternut. The dominant understory consists of flowering dogwood and American hornbeam, while a lower story may be composed of spicebush and bladdernut.

On the north- and east-facing slopes where the climax type is reached, the herbaceous flora may be dominated by liverleaf, early meadow rue, and thin grass. Bottlebrush, sweet cicely, narrow-leaved spleenwort, black snakeroot, baneberry, white snakeroot, and false hellebore may also occur.

In its final developmental stages, the flora of the sugar maple-white oak association closely approaches the composition of the floodplain association of sugar maple-bitternut hickory. The two arrive at nearly the same climax, and quite often a limestone hillside may show all stages of succession. However, the floodplain association begins as a hydrosere (its initial stage begins in or near water), while the sugar maple-white oak association begins as a xerosere (its initial stage begins where there exists an extreme deficiency of water, as on a bare limestone glade or rocky bluff).

c. Oak-Hickory Association. This is the common and prevailing association over most of the planning area's ridges, uplands, and upperhill slopes. It develops on drier and more acidic soils, and is probably the most complex association found in the region.

The oak-hickory association originates from a prairie association on an acid soil produced by sandstone, chert or granite bedrock. The first woody plants to invade the prairie flora are sassafras and winged sumac. Each forms local colonies and together they comprise the first seral stage of the association, the sassafras-winged sumac associes. Fragrant sumac and persimmon often occur in this stage. Grasses common at this stage are wild oat grass, slender fescue and panic grass (Panicum linearifolium).

By the next stage, the development of the forest flora is apparent because blackjack oak and post oak now penetrate the area. Usually these two species are already present in a forest area contiguous to the prairie, which is by now mostly pasture, and merely advance into the open area. In this associes the grasses of the preceding associes continue to occur, while broom sedge and several species of panic grasses are also found. This associes is the first of a later oak-hickory climax to invade the bald knobs and limestone glades of southern Greene County and northern Christian County.

The black oak-black hickory associes is the third stage of succession to develop. Black oaks grow fast and soon shade the light-demanding blackjack and post oaks marking the beginning of an end for the previous associes. The dominant understory shrubs of this associes consist of low-bush huckleberry and deerberry or farkleberry. Other herbs found in an acid soil flora include tick trefoil, lespedeza, scurf-pea, hawkweek, milk pea, rough goldenrod, summer grape, and New Jersey tea. Fragrant sumac, winged sumac and sassafras are commonly found in the blackjack-post oak stage.

Sometimes blackjack oak is absent from an area, leaving black oak, white oak, post oak, black hickory and shagbark hickory as associates. Black hickory is more common on ridges or plateau tops and on south- and west-facing slopes than on hills with north- or east-facing aspects.

The following herbs occur throughout all the associes: dittany, oats grass, pussy toes, goat's rue, lespedeza, panic grasses, cinquefoil, and several species of tick trefoils, sedges, asters, and goldenrods.

d. White Oak-Red Maple Association. This association commonly develops from drainages in acid soil, such as coves, heads of tributaries or streams, and upper slopes of hills and ravines. Development is initiated by pioneer trees that occupy a slight draw eroded by rainwater. Such trees could include flowering dogwood, blackgum, witch hazel, sassafras, and lesser stands of red maple.

As the drainage head becomes more deeply dissected, red maple along with mockernut hickory become the dominant species and form the second seral stage. In this associes smooth sumac, winged elm, and the serviceberry are also found with the other woody species from the preceding associes.

As the ravine deepens and more soil accummulates, the diversity of the forest is increased with the advent of white, scarlet, and black oaks. Northern red oaks and bitternut hickories may also occur in this associes.

In the final stage white oak becomes dominant with red maple to form the white oak-red maple associes. In this stage, blackgum and mockernut hickory are the tallest dominants, while flowering dogwood, sassafras, and serviceberry will form the understory. Shrubs include low-bush huckleberry, farkleberry, fragrant sumac, and greenbrier. Herbs consist of the usual dominants thin, rocky, acid soils catgut, dittany, bracken fern, lespedeza, tick trefoil, gerardia (*Gerardia grandiflora* and *G. pectinata*), stiff-leaf aster, goldenrod (*Solidago hispida*), and pasture rose.

As the headwaters enlarge the valley and ravine, the floras of the lower slopes and valley penetrate the richer slopes and the ravine bottom of the new drainage with such species as pawpaw, American hornbeam, spicebush, redbud, chinquapin oak, butternut, shagbark hickory, and mulberry. The flora of the ridge tops, plateaus, and upper slopes descends somewhat and overlaps that of the ravine. Thus, a very diversified flora may be encountered as a ravine is traced from its head down its course.

TABLE D-1
COMMON TREES AND SHRUBS IN THE SUGAR MAPLE-BITTERNUT HICKORY ASSOCIES

- Black Walnut
- Chinquapin Oak
- White Oak
- Blackgum
- Hazelnut
- Butternut
- Red Mulberry
- Shingle Oak
- Redbud
- Hawthorn species
- Linden
- Northern Red Oak
- Honey Locust
- Hackberry
- Bur Oak
- Winged Elm
- Red-flowered Buckeye
- Bladdernut
- Hop Hornbeam
- Elderberry
- Black Haw
- Chittimwood
- Moonseed
- Fragrant Sumac
- Black Cherry
- Ohio Buckeye

TABLE D-2
MAMMALS COLLECTED IN GREENE AND CHRISTIAN COUNTIES

Common Name	Scientific Name
Opossum	*Didelphis marsupialis*
Short-tailed Shrew	*Blarina brevicauda*
Least Shrew	*Crytotis parva*
Eastern Mole	*Scalopus aquaticus*
Little Brown Bat	*Myotis lucifugus*
Gray Bat	*Myotis grisescens*
Eastern Pipistrelle	*Pipistrellus subflavus*
Big Brown Bat	*Eptesicus fuscus*
Hoary Bat	*Lasiurus cinereus*
Cottontail Rabbit	*Sylvilagus floridanus*
Woodchuck	*Marmota monax*
Thirteen-lined Ground Squirrel	*Citellus tridecemlineatus*
Fox Squirrel	*Sciurus niger*
Eastern Gray Squirrel	*Sciurus carolinensis*
Southern Flying Squirrel	*Glaucomys volans*
Brush Mouse	*Peromyscus boylii*
Prairie White-footed Mouse	*Peromyscus maniculatus*
Woodland White-footed Mouse	*Peromyscus leucopus*
Common Cotton Rat	*Sigmodon hispidus*
Prairie Meadow Mouse	*Microtus ochrogaster*
*Southern Bog Lemming or Southern Lemming Mouse	*Synoptomys cooperi*
Norway Rat	*Rattus norvegicus*
House Mouse	*Mus musculus*
Red Fox	*Vulpes fulva*
Gray Fox	*Urocyon cinereoargenteus*
Raccoon	*Procyon lotor*
Stripped Skunk	*Mephitis mephitis*
Mink	*Mustela vison*
*Long-tailed Weasel	*Mustela frenata*

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*Species range includes the planning area, but presence is doubtful.

TABLE D-2 (Continued)
MAMMALS COLLECTED IN GREENE AND CHRISTIAN COUNTIES

*Fulvous Harvest Mouse	*Reithrodontomys fulvescens*
*Meadow Jumping Mouse	*Zapus hudsonius*
Beaver	*Castor canadensis*
*Spotted Skunk	*Spilogale putorius*
White-tailed Deer	*Odocoileus virginianus*
Bobcat	*Lynx rufus*
*Black-tailed Jack Rabbit	*Lepus californicus*
Eastern Chipmunk	*Tamaias striatus*
Eastern Wood Rat	*Neotoma floridana*
*Pine Mouse	*Microtus pinetorum*
Muskrat	*Ondatra zibethicus*
Coyote	*Canis lutrans*
*Badger	*Taxidea taxus*

* Species range includes the planning area, but presence is doubtful.

TABLE D-3
COMMON BIRDS OF GREENE AND CHRISTIAN COUNTIES

Pied-billed Grebe
Great Blue Heron
Green Heron
Mallard Duck
Gadwall Duck
Pintail Duck
Green-winged Teal Duck
Blue-winged Teal Duck
American Widgeon Duck
Lesser Scaup Duck
Turkey Vulture
Red-tailed Hawk
Osprey
Kestrel (Sparrow Hawk)
Bobwhite
American Coot
Killdeer
Rock Dove (pigeon)
Mourning Dove
Yellow-billed Cuckoo
Common Nighthawk
Chimney Swift
Ruby-throated Hummingbird
Belted Kingfisher
Common Flicker (yellow-shafted)
Red-bellied Woodpecker
Red-headed Woodpecker
Downy Woodpecker
Pileated Woodpecker
Eastern Kingbird
Great-crested Flycatcher
Eastern Phoebe Flycatcher
Eastern Wood Pewee
Carolina Wren
Mockingbird
Catbird
Brown Thrasher
Robin
Summer Tanager
Swainson's Thrush
Wood Thrush
Eastern Bluebird
Blue-gray Gnatcatcher
Ruby-crowned Kinglet
Loggerhead Shrike
Starling
Red-eyed Vireo
Warbling Vireo
Tennessee Warbler
Nashville Warbler
Northern Parula Warbler
Yellow Warbler
Yellow-rumped (Myrtle) Warbler
Yellowthroat Warbler
House Sparrow
Eastern Meadowlark
Red-winged Blackbird
Orchard Oriole
Common Grackle
Cowbird
Cardinal
Indigo Bunting
Dickcissel
Purple Finch
American Goldfinch

TABLE D-3 (Continued)
COMMON BIRDS OF GREENE AND CHRISTIAN COUNTIES

Rough-winged Swallow
Barn Swallow
Purple Martin
Blue Jay
Common Crow
Carolina Chickadee
Tufted Titmouse
White-breasted Nuthatch
House Wren
Barrel Owl
Great Horned Owl
Screen Owl
Rufous-sided Towhee
Junco (Slate-colored)
Tree Sparrow
Chipping Sparrow
Field Sparrow
White-crowned Sparrow
White-throated Sparrow
Song Sparrow
Turkey

TABLE D-4
REPTILES OF GREENE AND CHRISTIAN COUNTIES

Common Name	Scientific Name
Common Snapping Turtle	*Chelydra serpentina serpentina*
Aligator Snapping Turtle	*Macrociemys temmincki*
Stinkpot	*Stenotherus odoratus*
Three-toed Box Turtle	*Terrapene carolina triunguis*
Ornate Box Turtle	*Terrapene ornata ornata*
Map Turtle	*Graptemys geographica*
Mississippi Map Turtle	*Graptemys kohni*
Ouachita Map Turtle	*Graptemys pseudogeographica ouachitensis*
Western Painted Turtle	*Chrysemys picta belli*
Missouri Slider	*Pseudemys floridana hoyi*
Slider	*Pseudemys concinna hieroglyphica*
Red-eared Turtle	*Pseudemys scripta elegans*
Western Spiny Soft-shelled Turtle	*Trionyx spinifer hartwegi*
Smooth Soft-shelled Turtle	*Trionyx mutica mutica*
Eastern Collared Lizard	*Crotaphytus collaris collaris*
Northern Fence Lizard	*Sceloporus undulatus hyacinthus*
Western Slender Glass Lizard	*Ophisaurus attenuatus attenuatus*
Six-lined Race Runner	*Cnemidophorus sexlineatus*
Ground Skink	*Leilopisma laterale*
Five-lined Skink	*Eumeces fasciatus*
Broad-headed Skink	*Eumeces laticeps*
Southern Coal Skink	*Eumeces anthracinus pluvialis*
Graham's Water Snake	*Natrix grahami*
Blotched Water Snake	*Natrix erythrogaster transversa*
Diamond-backed Water Snake	*Natrix rhombifera rhombifera*
Northern Water Snake	*Natrix sipedon sipedon*
Midland Water Snake	*Natrix sipedon pleuralis*
Midland Brown Snake	*Storeria dekayi wrightorum* x *texana*

TABLE D-4 (Continued)
REPTILES OF GREENE AND CHRISTIAN COUNTIES

Northern Red-bellied Snake	*Storeria occipitomaculata occipitomaculata*
Western Ribbon Snake	*Thamnophis sauritus proximus*
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*
Red-sided Garter Snake	*Thamnophis sirtalis parietalis*
Rough Earth Snake	*Virginia striatula*
Western Earth Snake	*Virginia valeriae elegans*
Eastern Hognose Snake	*Heterodon platyrhinos*
Prairie Ringneck Snake	*Diadophis punctatus arnyi*
Western Worm Snake	*Carphophis amoenus vermis*
Eastern Yellow-bellied Racer	*Coluber constrictor flaviventris*
Eastern Coachwhip	*Masticophis flagellum flagellum*
Rough Green Snake	*Opheodrys aestivus*
Great Plains Rat Snake	*Elaphe guttata emoryi*
Black Rat Snake	*Elaphe obsoleta obsoleta*
Bull Snake	*Pituophis melanoleucus sayi*
Prairie King Snake	*Lampropeltis calligaster calligaster*
Speckled King Snake	*Lampropeltis getulus holbrooki*
Red Milk Snake	*Lampropeltis triangulum syspila*
Great Plains Ground Snake	*Sonoria episcopa episcopa*
Northern Flat-headed Snake	*Tantilla gracilis hallowelli*
Northern Copperhead	*Agkistrodon contortrix mokeson*
Western Cottonmouth	*Agkistrodon piscivorus leucostoma*
Western Pigmy Rattlesnake	*Sistrurus miliarius streckeri*
Timber Rattlesnake	*Crotalus horridus horridus*

TABLE D-5
AMPHIBIANS OF GREENE AND CHRISTIAN COUNTIES

Common Name	Scientific Name
*Hellbender	Cryptobranchus alleganiensis alleganiensis
Ringed Salamander	Ambystoma annulatum
Spotted Salamander	Ambystoma maculatum
*Marbled Salamander	Ambystoma opacum
Eastern Tiger Salamander	Ambystoma tigrinum tigrinum
Central Newt	Notophthalmus viridescens louisianensis
Long-tailed Salamander	Eurycea longicauda melanopleura
Cave Salamander	Eurycea lucifuga
Gray-bellied Salamander	Eurycea multiplicata griseogaster
Ozark Red-backed Salamander	Plethodon dorsalis angusticlavius
Slimy Salamander	Plethodon glutinosus glutinosus
Grotto Salamander	Typhlotriton spelaeus
Red River Waterdog	Necturus maculosus louisianensis
Dwarf American Toad	Bufo americanus charlesmithi
*Woodhouse's Toad	Bufo woodhousei woodhousei
Fowler's Toad	Bufo woodhousei fowleri
Blanchard's Cricket Frog	Acris crepitans blanchardi
Northern Spring Peeper	Hyla crucifer crucifer
Gray Treefrog	Hyla versicolor - chrysoscelis
Western Chorus Frog	Psedacris triseriata triseriata
Eastern Narrow-mouthed Toad	Gastrophryne carolinensis
Bullfrog	Rana catesbeiana
Green Frog	Rana clamitans melanota
Pickerel Frog	Rana palustris
Southern Leopard Frog	Rana sphenocephala
*Wood Frog	Rana sylvatica

* Species range include the planning area, but not known to be present.

GLOSSARY AND ABBREVIATIONS

Absorption - the process by which one substance is taken into and included within another substance, as the absorption of water by soil or nutrients by plants.

Absorption field - a system of buried perforated or discontinuous pipes (laterals) through which partially treated wastewater leaving a septic tank is distributed over an area for further treatment by percolation into the soil; same as "lateral field," or "leach field."

Activated sludge process - a biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

Aerobic - (1) having molecular oxygen as a part of the environment; (2) growing or occurring only in the presence of molecular oxygen, such as aerobic organisms.

Anaerobic - (1) the absence of molecular oxygen; (2) growing in the absence of molecular oxygen (such as anaerobic bacteria).

Aquiclude - an impervious layer of soil or rock which prevents the passage of water.

Aquifer - an underground, water-bearing stratum of permeable rock, sand, or gravel.

Aquitard - a layer of soil or rock which inhibits, but does not totally prevent, the passage of water.

Alluvial - relating to material deposited by a stream.

Avian - relating to birds.

Benthos - organisms dwelling on the bottom of a water body. Benthos include all organisms which crawl on, burrow into, or grow attached to, the bottom.

Biochemical oxygen demand (BOD) - the quantity of oxygen used in the biochemical decompositon of organic matter; used to indicate the amount of organic matter present in water; BOD_5 refers to a biochemical oxygen demand over a five-day period. BOD_5 is a standard test used to express the amount of decayable organic matter in water.

Biota - the plants and animals of an area, taken collectively.

Blackwater - liquid and solid human body waste and carriage waters generated through toilet usage.

Calcereous - consisting of or containing clacium carbonate.

cfs - cubic feet per second.

Chemical oxygen demand (COD) - a measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater.

Chlorination - disinfection of water by treatment with chlorine.

Chlorine residual - the total amount of chlorine (combined and free available chlorine) remaining in water, sewage, or industrial wastes at the end of a specified contact period following chlorination.

Clarifier - settling tanks. The purpose of a clarifier is to remove settleable solids by gravity, or colloidal solids by coagulation following chemical flocculation; will also remove floating oil and scum through skimming.

Clean Water Act - federal law passed in 1977 revising Federal Water Pollution Control Act Amendments of 1972; pertinent sections are 201, 208, and 303 (e).

cm - centimeters

COD - Chemical Oxygen Demand

Coliform-group bacteria - a group of bacteria predominantly inhabiting the intestines of man or animal, but also found elsewhere. Used as an indicator of contamination.

Combined sewers - sewers which contain sanitary sewage and storm water runoff. Combined sewer overflows (CSOs) occur when the storm water flows exceed the pipe capacity, causing the sewage/storm water mixture to backup and overflow into the surface drainage.

Complete-mix activated sludge system - a biological wastewater treatment process in which a mixture of wastewater and bacteria is agitated and mechanically aerated, allowing bacterial decomposition of waste solids; bacteria and remaining solids are subsequently separated from the treated wastewater by settling, and disposed of or returned to the process as needed.

Construction Grants program - a program administered by EPA to carry out the mandate of the Clean Water Act to assist local communities in funding municipal wastewater facilities.

Design flow - the volume of wastewater a facility is expected to process in a given length of time; usually the average daily amount of wastewater expected to be produced in a facility's service area 20 years after its construction.

Digestion - the biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.

Dip - the angle that a structural geologic surface makes with the horizontal, measured perpendicular to the line formed by the intersection of the surface with the horizontal.

Disinfection - killing pathogenic microbes on or in a material without necessarily sterilizing it.

Dissolved oxygen (DO) - the oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter (mg/l), parts per million (ppm), or percent of saturation.

DO - dissolved oxygen.

Ecosystem - a system formed by the interaction of a group of organisms and their environment.

Effluent - sewage, water, or other liquid, partially or completely treated or in its natural state, flowing out of a reservoir, basin, or treatment plant.

EIS - Environmental Impact Statement.

EPA - U. S. Environmental Protection Agency.

Eutrophic - a term applied to water that has a concentration of nutrients optimal, or nearly so, for plant or animal growth.

Eutrophication - the process of maturation of a lake from nutrient-poor to nutrient-rich. The artificial addition of nutrients to lakes accelerates the process. This condition is often characterized by excessive algal growths which may cause aesthetic problems, e.g., foul odors or unsightly appearance, or in severe cases, even fishkills.

Extended aeration - a complete-mix activated sludge system in which the amount of influent wastes is relatively small compared to the amount of bacteria in the system, requiring longer detention times than conventional complete-mix activated sludge processes and resulting in less sludge wastes.

Extraneous Flow Basins - lagoonlike structures designed to retain flow above the capacity of a wastewater treatment facility during periods of high flow, and feed it back to the facility during periods of lower flows.

Facilities Plan - a preliminary engineering report on proposed wastewater treatment facilities; developed to fulfill Step 1 requirements of EPA's Construction Grants program; analyzes treatment needs, alternative treatment methods, existing sewer system adequacy, and costs; includes an environmental assessment; also referred to as a "201 plan," after Section 201 of the Clean Water Act.

Fauna - the animal life of an area.

Fecal coliform bacteria - group of bacteria present in human and other warm-blooded animal intestines and excreted in feces; while generally harmless in themselves, fecal coliforms may indicate the presence of pathogens.

FEMA - Federal Emergency Management Agency

FIA - Federal Insurance Administration

Filtrate - the liquid which which has passed through a filter.

Floodplain - the land adjacent to a river channel which is covered with water when the river overflows its banks.

Flora - the plant life of an area.

Force main - a sewer through which wastewater is pumped.

fps - feet per second.

ft - feet

FWPCA - The Federal Water Pollution Control Act.

FWS - U.S. Dept. of the Interior, Fish and Wildlife Service.

g - acceleration equivalent t the force of gravity.

Genus (plural-genera) - group of related animals or plants ranking below a family and above a species.

gpcd - gallons per capita per day.

gpd - gallons per day.

gpm - gallons per minute.

Gravity sewer - a sewer in which the wastewater flows downhill from source to outlet, with no pumping required.

Graywater - wastewater generated by water-using fixtures and appliances, excluding the toilet and possibly the garbage disposal.

Grit removal - initial phase of primary treatment in which large solids - generally inorganic ones - are removed.

Habitat - the place where an organism lives.

I/I - the combined extraneous wastewater flow from infiltration and inflow.

Infiltration - (1) movement of water downward into the soil; (2) water entering a sewer system underground by such means as cracks in sewer pipes and manholes and leaky pipe joints, usually caused by a water table above the level of the sewer.

Inflow - water other than sewage entering a sewer system directly by such means as connections with storm sewers, roof and foundation drains, sump pumps, and holes in manhole covers.

Influent - wastewater entering a wastewater facility or component thereof.

Interceptor sewer - a sewer receiving flows from collector lines and carrying them to a central point for treatment and discharge.

Intermittent stream - a stream or a reach of a stream that flows only at certain times of the year.

Karst - a limestone region characterized by the predominance of solution features such as sink holes and caverns and by the resultant subsurface drainage.

km - kilometer

Lagoon - a large pond in which wastewater is retained for primary and/or secondary treatment; discharging lagoons produce an effluent, non-discharging lagoons rely entirely on evaporation for disposal of water.

Land treatment - wastewater treatment by the action of bacteria present in the soil following its application onto the surface of the ground; accomplished by overland flow, rapid infiltration, or slow infiltration.

lf - linear feet

Lift station - a wastewater pumping station that lifts wastewater to a higher elevation when the continuance of the gravity sewer at reasonable slopes would involve excessive depths of trench.

Loess - a shallowly buried layer of windblown dust of relatively recent geologic age; generally nonstratified, porous, unconsolidated and fine-grained, consisting predominantly of silt.

Losing stream - a stream in which the flow decreases with distance downstream through losses to permeable soil or cavernous bedrock. The Missouri DNR defines a losing stream as one which distributes 30 percent or more of its flow into groundwater by means of natural processes.

MDNR - the Missouri Department of Natural Resources

mcl - maximum contaminant level, in drinking water regulations.

mgd - million gallons per day.

mg/l - milligrams per liter; approximately equivalent to parts per million.

mi - mile

msl - mean sea level.

Mitigating measure - action taken to lessen or eliminate an adverse environmental impact.

Mixing zone - that portion of a stream from the point at which effluent is introduced downstream to the point at which it is uniformly mixed with the receiving waters.

NEPA - National Environmental Policy Act of 1969.

Nitrification - biological oxidation of ammonium to nitrate.

Nonpoint-source discharge - general source of pollution entering a body of water and not originating from a single controllable source, e.g., runoff from farmland.

Notice of Intent - announcement by a Federal agency of its intent to prepare an EIS.

NPDES - National Pollutant Discharge Elimination System.

O&M - operation and maintenance

Oxidation ditch - method of sewage treatment using a ring-shaped channel, about 3 ft. deep, and a rotor to provide circulation and aeration.

Package plant - a small wastewater treatment plant whose various components are contained within one structure, purchased and installed as a unit.

Particulates - minute, separate particles dispersed in the air, contributing to pollution; main sources are coal combustion, industrial processes, and forest fires.

Pathogen - disease-producing organism.

PE - population equivalent

Percolation - movement of water through soil; empirically measured by a test in which a hole is drilled in the soil and soaked, then filled with water, and the rate of downward movement of the water surface recorded, given in minutes per inch; does not necessarily correlate directly to permeability.

Perennial stream - a stream or a reach of a stream that flows continuously throughout the year.

Permeability - quality of soil that permits it to transmit water; empirically measured by rate of downward movement of water through saturated soil cores; given in inches per hour; does not necessarily correlate directly to percolation.

pH - a term used to describe the hydrogen-ion activity of a system.

Physiographic province - any large geologic area or region considered as a whole, all parts of which are characterized by similar landform features or history, and differ significantly from those of adjacent areas.

Planning area - area covered by a facilities plan.

ppm - parts per million; approximately equivalent to milligrams per liter.

Point-source discharge - introduction of treated or untreated wastewater into a body of water at a discrete point of discharge, such as a pipe.

Primary impact - direct effect of an action.

Primary treatment - the first major process in most wastewater treatment plants; consisting of retaining wastewater in a tank long enough for solids to settle.

Prime agricultural land - land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and which is available for one of these uses; rated in Class I or II in SCS's agricultural capability classification system.

RDF - refuse-derived fuel.

Riparian woodland - an area of trees and other woody vegetation bordering a stream or lake.

SCS - Soil Conservation Service, a branch of the U.S. Department of Agriculture.

Secondary impact - an indirect effect of an action; for example, population growth induced by the provision of sewerage service.

Secondary treatment - removal of organic wastewater constituents, usually by microbial activity, following primary treatment (settling); a plant is generally recognized as providing secondary treatment if its effluent contains no more than 30 mg/l each of BOD_5 and suspended solids, or if at least 85% of BOD_5 and suspended solids are removed from the effluent, whichever is the stricter standard.

Section 201 - portion of Clean Water Act providing for federal assistance in the construction of municipal wastewater facilities.

Section 208 - portion of Clean Water Act requiring, and providing for federal assistance in, water quality management planning for counties or multiple-county areas; 208 plans are used to guide all county water pollution control efforts in accordance with federal, state, and local requirements.

Section 303(e) - section of Clean Water Act mandating continuous statewide water quality planning; 303 plans generally encompass entire major river basins, and identify general areas of water quality standards violations.

Sedimentation basin - a basin or tank in which wastewater is retained to allow suspended matter to settle.

Septic tank - a component for partial on-site treatment of wastewater, usually for individual residences, by means of settling and decomposition by anaerobic microorganisms; must be paired with an absorption field for complete treatment.

Septic tank system - wastewater treatment system consisting of a septic tank and absorption field.

Service area - area intended to be served by a given wastewater facility.

SHPO - State Historic Preservation Officer

Siltation - the accumulation by deposition of silt in a body of water.

Sludge - accumulated solids separated from liquids, such as water or wastewater, during treatment or processing.

Species - any group of organisms which interbreed when mature.

sq. mi. - square miles.

SSES - sewer system evaluation survey. A study to identify problems where excessive I/I are indicated.

Step 1 - first stage of a project funded under EPA's Construction Grants program: development of a Facilities Plan.

Step 2 - second stage of a project funded under EPA's Construction Grants program: development of design drawings and specifications.

Step 3 - third stage of a project funded under EPA's Construction Grants program: construction.

Stratum (plural, strata) - a sedimentary bed or layer, visually separable from other layers.

Suspended solids (SS) - particles dispersed within, but not dissolved in, wastewater; if water is allowed to stand, suspended matter will eventually float to the top or settle to the bottom; dissolved matter (for instance, table salt or sugar) will not.

Taxa (plural of taxon) - a group of organisms constituting one of the categories or formal units in taxonomic classification, such as phylum, order, family, genus, or species, and characterized by attributes in varying degrees of distinction.

THMs - trihalomethanes, a specific group of volatile organic compounds produced in water treatment by the reaction of chlorine and naturally-occurring (usually) organic compounds. High concentrations of trihalomethanes are suspected to cause cancer.

Trickling filter - A sewage treatment system in which wastewater is passed through a media bed, usually rocks, for removal of organics by bacteria growing on the media.

Troglobite - a cave-dwelling organism. An obligate troglobite is an organism that can only exist in total darkness.

TSS - total suspended solids, see "suspended solids."

Turbidity - cloudiness of water brought about by the presence of silt or other suspended solids.

USDA - United States Department of Agriculture.

USGS - United States Geological Survey, Dept. of the Interior.

Water table - that level in saturated soil where the hydraulic pressure is zero.

Water table, perched - the water table of a discontinuous saturated zone in a soil.

WWTP - wastewater (sewage) treatment plant.

ENGLISH UNIT/METRIC UNIT CONVERSION FACTORS

Multiply (English Units)		by	To obtain (Metric Units)	
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F	0.555 (°F-32)*	°C	degree centigrade
feet	ft	0.3040	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig + 1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

* Actual conversion, not a multiplier

Source: McCandless, Lee C., and Robert B. Shaver. 1978. Assessment of coal cleaning technology: first annual report, U.S. Environmental Protection Agency, Office of Research and Development, Industrial Environmental Research Laboratory, Research Triangle Park NC, EPA-600/7-78-150, 153 p.

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